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LEFT FOOT ACCELERATOR PEDAL EVALUATION

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by
James C. Patry and Suanne L. Dorion
Blackwater Ltd.

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16. Abstract

The left foot accelerator pedal (LFAP) is a mechanical adaptive device allowing left foot operation of the accelerator. This device is mounted on the left side of the brake pedal and activates the right-side accelerator, which is not removed. This report reviews the collected information to determine the need for standards or guidelines to govern the design, manufacture, installation, prescription and use of LFAPs in a safe manner.

This report also details the current situation in the marketplace for LFAPs. Accident and incident data involving LFAPs are described, and existing related standards and guidelines are reviewed. LFAP products most commonly installed by mobility equipment dealers/installers in Canada are identified. Analysis of the devices reveals the features offered to drivers with disabilities and the modifications required for installation in a vehicle. A review of the installation process – a critical element in the safety of the completed installation – is described, as is an ergonomics review in the form of a task and error analysis of driver and installer actions to identify potential errors and consequences of those actions. Occupational therapists, driving instructors, drivers, installers and manufacturers were consulted to assist in determining areas of consideration for the development of a standard or guideline.

The report concludes with a discussion of the need for a standard or guideline governing the design, manufacture, installation, prescription and use of LFAPs, and explores the options for implementing a standard in Canada.

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16. Résumé

La pédale d'accélérateur pour pied gauche est une aide mécanique à la conduite qui permet de commander l'accélérateur à l'aide du pied gauche. Le dispositif est monté à gauche de la pédale de frein et il actionne la pédale d'accélérateur «normale», située à droite de la pédale de frein. Ce rapport présente l'information recueillie aux fins d'évaluer le besoin de normes et de lignes directrices pour régir la conception, la fabrication, l'installation, la prescription et l'utilisation des pédales d'accélérateur pour pied gauche, le tout dans un souci de sécurité.

Le rapport présente la place actuelle des pédales d'accélérateur pour pied gauche sur le marché. Il passe en revue les données sur les accidents et les incidents mettant en cause ce dispositif, de même que les normes et les lignes directrices en vigueur. Sont également répertoriés les dispositifs les plus couramment installés par les vendeurs/installateurs d'aides spécialisées à la conduite au Canada. L'analyse des dispositifs met en lumière les atouts qu'ils représentent pour les conducteurs handicapés et les modifications que nécessite leur installation dans le véhicule. Le rapport rend compte d'une revue de la méthode d'installation - un facteur crucial de la sûreté du produit - et d'une évaluation ergonomique, qui a consisté en une analyse des tâches des conducteurs et des installateurs, des erreurs auxquelles elles peuvent donner lieu, et des conséquences de ces erreurs. Des ergothérapeutes, des moniteurs de conduite, des conducteurs, des installateurs et des fabricants ont été consultés sur les questions à prendre à considération dans l'élaboration d'une norme ou d'une ligne directrice.

Le rapport se termine par une discussion de la nécessité d'une norme ou d'une ligne directrice pour régir la conception, la fabrication, l'installation, la prescription et l'utilisation des pédales d'accélérateur pour pied gauche, et explore les diverses options pour la mise en oeuvre d'une norme au Canada.

17. Mots clés	18. Diffusion
Aides spécialisées, normes, lignes directrices, modifications à un véhicule, pédale d'accélérateur pour pied gauche	Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

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EXECUTIVE SUMMARY

The left foot accelerator pedal (LFAP) is an inexpensive low-tech device commonly prescribed by driver rehabilitation specialists to allow persons who cannot use their right foot to operate a motor vehicle. The LFAP is a mechanical adaptive device that allows left foot operation of the accelerator. This device is mounted on the left side of the vehicle brake pedal and activates the Original Equipment Manufacturer (OEM) accelerator, which is not removed.

This project was initiated in response to a request from the Transportation Development Centre (TDC) to conduct technical and ergonomics evaluations of the LFAP to determine the degree to which equipment failure, poor installation, ergonomic considerations, and/or driver error are responsible for accidents/incidents. Although great progress has been made by manufacturers and mobility equipment dealers in the field of automotive adaptive devices, the performance and safety of LFAPs is not currently regulated by Canadian standards or guidelines. The results of this project will provide a foundation for a preliminary working document for subsequent development of safety standards and guidelines.

There are two types of LFAPs: removable and permanent. The removable type allows the LFAP assembly to be removed from the vehicle, leaving a low profile base plate in place. The removable type permits nondisabled drivers to operate the vehicle by effectively returning the vehicle to OEM conditions. The permanent type is mounted in a fixed position and remains in the vehicle regardless of the driver (the left-side pedal assembly can be folded out of the way to permit nondisabled drivers to operate the vehicle using the OEM accelerator pedal). The trend over the past three years has been a move toward the removable type as it is currently the most commonly sold and because production of permanently mounted LFAPs has been discontinued by several manufacturers.

Various sources were contacted to obtain relevant accident and incident data, and existing standards and/or guidelines related specifically to the use of LFAP devices. Accident/incident statistics and reports available do not reveal a high or unusual occurrence of incidents involving LFAPs. Existing documentation (industry association recommendations, best practices, guidelines) is minimal and general in nature.

The Canadian market for LFAPs is small (estimated between 200 and 300 per year) and the price is low, in comparison with other automotive adaptive devices. LFAP models from five manufacturers, identified as the LFAP products most commonly purchased and installed, were selected for further study.

An engineering review, in the form of a technical evaluation and trial installation of the selected LFAPs, revealed various technical deficiencies in LFAP design – the technical deficiencies varied from device to device. Trial installations revealed that some vehicles are not suitable for the installation of an LFAP. The manufacturers' installation

instructions and owner's manuals revealed various deficiencies in the instructions – the deficiencies in the instructions varied from device to device. In general, there is a lack of consolidated procedures of any kind for the design, manufacture, installation, maintenance, installer training and driver training related to LFAPs in Canada and the U.S.

An ergonomics review of the user and installer actions identified potential errors and consequences of those actions. There is a lack of a defined or documented LFAP prescription process that identifies the LFAP as a suitable adaptive aid for a driver. In general, there is a lack of evidence that all processes – from the prescription of to driving with an LFAP – are adequately supported to ensure safe operation.

Occupational therapists, driving instructors, drivers, installers and manufacturers were consulted to determine areas of consideration for the development of a standard or guideline.

Based on the engineering and ergonomic reviews of design, manufacture, installation, prescription, driver assessment and driver training, a need exists in the industry for documentation to provide standardization, whether in the form of best practices, guidelines, industry standards or legislated standards. Producing a Canadian legislated standard by the Government of Canada independent of other organizations, considering the small market and the low number of incident reports, is not likely a realistic, cost-effective option. The most efficient method of implementing a standard in Canada for LFAPs would be the direct adoption of released Society of Automotive Engineers (SAE) documents by recognized industry associations such as the National Mobility Equipment Dealers Association and the Association for Driver Rehabilitation Specialists.

Future work, including surveys and studies, should focus on providing resources to assist the LFAP Sub-committee of the SAE Adaptive Devices Committee in the development of a standard for the prescription, design, manufacture, installation and use of LFAPs that would include driver issues and contain advisory appendices on a broad range of factors such as:

- methods to assess user abilities;
- licensing requirements;
- vehicle selection;
- documentation format;
- ergonomic considerations; and
- advisory notes.

Participation by TDC/Transport Canada on the SAE LFAP Sub-committee should be provisional on the inclusion of advisory appendices in the SAE technically oriented recommended guideline.

SOMMAIRE

La pédale d'accélérateur pour pied gauche est un dispositif à faible technicité et peu coûteux, couramment prescrit par les spécialistes de la réadaptation à la conduite automobile. Elle permet à une personne n'ayant pas l'usage de son pied droit de conduire un véhicule automobile. Il s'agit en effet d'une aide mécanique à la conduite qui permet de commander l'accélérateur à l'aide du pied gauche. Le dispositif est monté à gauche de la pédale de frein et il actionne la pédale d'accélérateur installée par le constructeur OEM (Original Equipment Manufacturer), qui reste en place.

Ce projet fait suite à une demande du Centre de développement des transports (CDT) de réaliser des évaluations technique et ergonomique de la pédale d'accélérateur pour pied gauche afin de déterminer les parts respectives imputables à la défaillance du dispositif, à une installation déficiente, aux facteurs ergonomiques et/ou à l'erreur du conducteur dans les accidents/incidents mettant en cause ce dispositif. Des progrès immenses ont été accomplis par les constructeurs et les équipementiers dans le domaine des aides à la conduite. Mais la performance et la sûreté des pédales d'accélérateur pour pied gauche ne sont encore régies par aucune norme ou ligne directrice au Canada. Les résultats de ce projet serviront d'assise à un document de travail préliminaire en vue de l'élaboration ultérieure de normes et de lignes directrices en matière de sécurité.

Il existe deux modèles de pédales d'accélérateur pour pied gauche : le modèle amovible et le modèle fixe. Le modèle amovible peut être enlevé : il est alors remplacé par une plaque de base affleurant le plancher. Ce type de pédale permet à un conducteur non handicapé de conduire le véhicule dans sa configuration d'origine. Le modèle fixe est monté à demeure et il reste en place, quel que soit le conducteur (la pédale pour pied gauche peut toutefois être escamotée de façon que les conducteurs ayant l'usage de leur pied droit puissent conduire le véhicule en utilisant la pédale d'accélérateur OEM). La tendance en faveur du modèle amovible s'est affermie ces trois dernières années. En effet, il s'agit du modèle le plus couramment vendu à l'heure actuelle, et plusieurs fabricants ont cessé de produire les modèles fixes.

Les chercheurs ont communiqué avec diverses sources pour obtenir des données accidentologiques pertinentes, et pour consulter les normes et/ou lignes directrices en vigueur concernant l'utilisation de la pédale d'accélérateur pour pied gauche. Les statistiques et les rapports sur les accidents/incidents consultés ne révèlent pas un taux élevé ou inhabituel d'incidents mettant en jeu les pédales d'accélérateur pour pied gauche. Quant aux documents normatifs (recommandations formulées par les associations industrielles, guides de meilleures pratiques, lignes directrices) ils sont peu nombreux et à caractère général.

Le marché canadien des pédales d'accélérateur pour pied gauche est restreint (on estime entre 200 et 300 par année les ventes de ces dispositifs) et leur prix est faible,

si on le compare à celui d'autres aides à la conduite. Les modèles de cinq fabricants les plus couramment vendus et installés ont été retenus pour une étude plus approfondie.

Un examen technique, soit une évaluation technique et une installation d'essai des dispositifs sélectionnés, a révélé diverses lacunes dans la conception des pédales d'accélérateur pour pied gauche – lacunes qui différaient d'un dispositif à l'autre. Quant aux installations d'essai, elles ont permis de constater que certains véhicules sont peu indiqués pour l'installation d'une pédale d'accélérateur pour pied gauche. Les guides d'installation des fabricants et les manuels de l'usager contenaient diverses lacunes – qui différaient elles aussi d'un dispositif à l'autre. Règle générale, on note l'absence de toute codification des méthodes en ce qui a trait à la conception, à la fabrication, à l'installation et à l'entretien des dispositifs, ainsi qu'à la formation des installateurs et à la formation des conducteurs, tant au Canada qu'aux États-Unis.

L'évaluation ergonomique a porté sur les gestes des conducteurs et des installateurs. Elle a permis de cerner les erreurs potentielles dans l'accomplissement de ces gestes, de même que les conséquences de ces erreurs. Il n'existe pas vraiment de processus défini ou documenté pour la prescription du dispositif, qui permettrait de déterminer que ce dispositif constitue une aide à la conduite appropriée pour un conducteur donné. Bref, d'après les faits observés, on ne peut affirmer que tous les processus – de la prescription d'une pédale d'accélérateur pour pied gauche à la conduite d'un véhicule muni de ce dispositif – sont de nature à garantir la sécurité.

Les ergothérapeutes, les moniteurs de conduite, les conducteurs, les installateurs et les fabricants ont été consultés sur les questions à prendre en considération dans l'élaboration d'une norme ou d'une ligne directrice.

Les études technique et ergonomique de la conception, la fabrication, l'installation et la prescription des dispositifs, et l'évaluation des conducteurs et de la formation destinée aux conducteurs ont fait ressortir la nécessité pour l'industrie de disposer de documents normatifs, que ce soit sous la forme de meilleures pratiques, de lignes directrices, de normes industrielles ou de normes réglementaires. L'élaboration d'une norme réglementaire canadienne par le gouvernement du Canada seul, indépendamment de toute autre organisation, n'est probablement pas une option réaliste ni économique, compte tenu de la petitesse du marché et du peu d'accidents dénombrés. La façon la plus efficiente de mettre en oeuvre une norme touchant les pédales d'accélérateur pour pied gauche au Canada serait que les associations industrielles reconnues, comme la National Mobility Equipment Dealers Association (NMEDA) et l'Association for Driver Rehabilitation Specialists adoptent tels quels les documents publiés par la SAE (Society of Automotive Engineers).

Les travaux futurs (enquêtes ou recherches) devront viser à appuyer le sous-comité sur les pédales d'accélérateur pour pied gauche du Adaptive Devices Committee de la SAE dans l'élaboration d'une norme touchant la prescription, la conception, la fabrication, l'installation et l'utilisation de pédales d'accélérateur pour pied gauche. Cette norme

devrait aborder les questions intéressant les utilisateurs et contenir des annexes tenant lieu de documents de référence sur un large éventail de sujets comme :

- méthodes d'évaluation des capacités des conducteurs;
- exigences relatives à l'émission des permis de conduire;
- choix du véhicule;
- format de la documentation;
- facteurs ergonomiques;
- mises en garde.

La participation du CDT/Transports Canada au sous-comité de la SAE sur les pédales d'accélérateur pour pied gauche devrait être conditionnelle à l'inclusion d'annexes de référence dans la ligne directrice à caractère technique recommandée par la SAE.

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GLOSSARY

The following is an alphabetical list of the acronyms, abbreviations and definitions of terms used in this report. For brevity, acronyms and abbreviations will not be defined in the text.

ADC — Adaptive Device Committee.

ADED — Association of Driver Rehabilitation Specialists.

CBDI — Cognitive Behaviour Driving Inventory.

CSA — Canadian Standards Association.

Certified Driver Rehabilitation Specialist — a driver rehabilitation specialist who is certified by ADED.

CMVSS — Canadian Motor Vehicle Safety Standard.

DOT — Department of Transportation (U.S.).

Driver — the user of the left foot accelerator pedal.

Driver Rehabilitation Specialist — one who plans, develops, coordinates and implements driver rehabilitation services for individuals with disabilities.

FMVSS — Federal Motor Vehicle Safety Standard (U.S.).

GVWR — Gross Vehicle Weight Rating.

Installer — any company or individual that represents a product manufacturer and is authorized to sell and/or install that manufacturer's products. Also known as a Mobility Equipment Dealer.

LFAP (Left Foot Accelerator Pedal) — a term used to refer to:

- A mechanical device that allows left foot operation of the accelerator (source: SAE J2094, June 1992);
- A device mounted on the left side of the vehicle brake pedal that activates the OEM accelerator, which is not removed (source: N.M.E.D.A. Guidelines, revised 12/22/99).

Mobility Equipment Dealer — an individual or company that converts or modifies vehicles for use by persons with disabilities.

MVSA — Canadian Motor Vehicle Safety Act.

NHTSA — National Highway Traffic Safety Association.

N.M.E.D.A. — National Mobility Equipment Dealers Association.

Nondisabled Driver — the driver for whom the OEM vehicle was originally designed.

OEM (Original Equipment Manufacturer) — a term used to refer to the vehicle manufacturer, or to the vehicle and vehicle components as they are designed and produced by the vehicle manufacturer.

OT (Occupational Therapist) — one who uses specialized knowledge to help individuals perform daily living skills and achieve maximum independence.

Physical Disability — the absence or reduction of a neuromuscular or orthopedic function of the human body.

QAP — Quality Assurance Program.

SAE — Society of Automotive Engineers.

1 INTRODUCTION

The left foot accelerator pedal (LFAP) is an inexpensive low-tech device commonly prescribed by driver rehabilitation specialists to allow persons who cannot use their right foot to operate a motor vehicle. Persons with amputations or right hemiplegia from any number of causes (such as traumatic nerve or muscular damage, post polio effects, stroke, multiple sclerosis, arthritic damage and others) benefit from this automotive adaptive aid.

Because the LFAP is low-tech, it runs the risk of being installed by technicians who lack specific installation training, and without the advice of a driver rehabilitation specialist. Such devices may be installed in a vehicle without a doctor's referral or a rehabilitation assessment to determine the most appropriate adaptive aid for the particular driver. In some cases, there may be an insufficient amount of driver and/or installer training and instruction. A common training program may not suit all drivers as different learning, confidence and skill levels will affect the outcome of any training.

Because LFAPs are not frequently used, and given that a large proportion of the population have a dominant right leg, it can be assumed that there may be some performance difficulties associated with the use of an LFAP. It may, however, be the most suitable alternative to allow persons who cannot use their right leg as a result of a disability to continue driving. One of the benefits of using an LFAP is that it can be installed into most vehicles with automatic transmission and its design allows the vehicle to be suitable for both disabled and nondisabled drivers.

From accident reports and anecdotal accounts, the LFAP has been involved in a number of accidents and incidents. Specialists in rehabilitation have therefore identified the need for safety standards related to the device, possibly for both mechanical performance and driver training.

This report evaluates the technical quality and installation of the devices, as well as the human behaviour involved in the driving task. The results are expected to determine the degree to which equipment failure, poor installation and ergonomic considerations, and/or driver error are responsible for accidents/incidents. The report will also become a preliminary working document for the subsequent development of safety standards and guidelines.

1.1 Project Objectives

The research and evaluations described in this report were conducted by Blackwater Ltd. and its subcontractor PHF Services Inc. for the Transportation Development Centre (TDC) of Transport Canada. The initial objective of the project was to conduct technical and ergonomics evaluations of the LFAP, covering its design and installation as well as its use/misuse.

From an engineering perspective, the objectives of this study are to define the desirable technical elements of the design and installation, and to outline guidelines, as required, to ensure that these elements are present.

The purpose of addressing human performance issues within this study is to ensure that the process employed to authorize and implement the use of the LFAP ensures its safe, efficient and effective use. The objectives of this report from an ergonomics perspective are to define the desirable elements of the process to authorize, implement and use the LFAP, and to outline guidelines that can be developed, if necessary, to ensure that these elements are present in the design and installation of LFAPs.

Although great progress has been made by mobility equipment dealers and manufacturers of these types of products, the performance and safety of LFAPs are not currently regulated by Canadian standards or guidelines. The results of this project will provide a foundation for a preliminary working document for the subsequent development of safety standards and guidelines.

2 REVIEW OF CURRENT SITUATION

To provide an accurate engineering and ergonomics assessment, the current situation concerning LFAPs must be determined.

2.1 Left Foot Accelerator Pedal Description

The following terminology and definitions were obtained from the Society of Automotive Engineers (SAE) and the National Mobility Equipment Dealers Association (N.M.E.D.A.), respectively:

- A mechanical device that allows left foot operation of the accelerator (source: SAE J2094, June 1992);
- This device is mounted on the left side of the vehicle brake pedal and activates the Original Equipment Manufacturer (OEM) accelerator, which is not removed (source: N.M.E.D.A. Guidelines, revised 12/22/99).

There are two types of LFAPs: removable and permanent. The removable type allows the LFAP assembly to be removed from the vehicle, leaving a low profile base plate in place. The removable type permits nondisabled drivers to operate the vehicle by effectively returning the vehicle to OEM conditions. The permanent type is mounted in a fixed position and remains in the vehicle regardless of the driver (the pedal assembly can be folded out of the way to permit nondisabled drivers to operate the vehicle using the OEM accelerator pedal).

The removable type is typically mounted on the driver's side floor. The permanent type can be either mounted on the floor on the driver's side or suspended from the firewall or steering column. The trend over the past three years has been a move toward the removable type as it is currently the most commonly sold and because production of permanently mounted LFAPs has been discontinued by several manufacturers.

The LFAP assembly consists of three main components: the left side accelerator pedal, the mounting block/plate and the actuator arm to the OEM accelerator pedal. A pedal stop/guard positioned over the OEM accelerator pedal is a feature on some LFAP models.

Installation conditions are two-fold: the LFAP must be capable of being installed into many different types of vehicles to allow operation by drivers with varying disabilities; and the installation must allow the vehicle to be returned to OEM conditions to allow operation by a nondisabled driver. In addition, it is important to note that the OEM designed the accelerator pedal and other controls to permit operation by the right foot. As a result, LFAP installation must take into account that the driver activates the brake using the left foot instead of the right foot for which it was designed.

The best designed and manufactured systems can be rendered useless and unsafe through poor installation or improper training, or by being the wrong adaptive modification for the driver's abilities.

2.2 Manufacturers/Distributors Summary

Various sources were used to identify the manufacturers and dealers in Canada and the United States. These sources included a mobility equipment manufacturers list generously provided by the Center for Biomedical Engineering and Rehabilitation Science at Louisiana Tech University, and the ABLEDATA database, a U.S. federally funded project that provides information on assistive technology and rehabilitation equipment. Manufacturers and distributors were asked which LFAP models were most commonly sold, particularly in Canada. A more challenging question was an estimation of the number of LFAPs installed in Canada in a given year.

A number of manufacturers of adaptive equipment have discontinued manufacture of their model of LFAP or supply very limited quantities of products to Canadian customers. As a result, the following manufacturers were excluded from the study:

- Creative Controls, Inc. (CCI) of Troy, Michigan, stopped manufacturing its permanent floor-mounted left foot accelerator (model 5000) about two years ago as a result of insufficient sales. CCI continues to manufacture other adaptive aids as part of its product line. It does, however, offer installation of the MPS left foot accelerator pedal to customers as part of its service offering. CCI opted for the MPS model because of its quick release feature, overall performance and ease of installation.
- Gresham Driving Aids Inc. of Wixom, Michigan, stopped manufacturing its permanent floor-mounted left foot accelerator about five years ago. No reason was cited. The company does, however, continue to manufacture other adaptive aids as part of its product line. Gresham Driving Aids offers installation of the MPS left foot accelerator pedal to customers as part of its service offering because the unit is easily detachable from the vehicle and allows for a nice neat installation.
- Wells-Engberg Co., Inc. of Rockford, Illinois, stopped manufacturing its permanently mounted model and its portable left foot accelerator about a year ago. The portable device was based on the MPD model; however, when MPD changed its design, Wells-Engberg could no longer use it. It does, however, continue to manufacture other adaptive aids as part of its product line. It currently distributes the MPS and MPD devices as part of its service offering.
- Handicaps Inc. of Englewood, Colorado, has been manufacturing its permanent floor-mounted left foot accelerator pedal model #104 since 1969. A pedal stop/guard to shield the OEM accelerator, model #103, can be

purchased and the LFAP is designed to fold down flat when not in use. Handicaps Inc. stated that few of its LFAPs have been sold in Canada.

- Kroepke Kontrols Inc. of Bronx, New York, has been manufacturing its left foot accelerator pedal models since 1952. One model is a permanent floor-mounted version and the other model suspends from the steering column. Kroepke Kontrols stated that very few of its LFAPs have been sold in Canada.

The following manufacturers were selected for further study based on consultations with various representatives in the adaptive aids industry in Canada and the U.S.:

- Drive-Master Co., Inc., or Guidosimplex;
- driving Systems incorporated (dSi), or FujiAuto;
- Howell Ventures Ltd.;
- Mobility Products and Design (MPD), or Braun/Crow River Inc.; and
- Manufacturing and Production Services Corporation (MPS).

Sections 2.2.1 through 2.2.5 provide summaries of the LFAP models supplied by each of these manufacturers/distributors. Sample products were purchased from or donated by manufacturers/distributors of LFAPs for the purposes of this project. Technical information on the products was extracted from product sales literature, installation manuals and owner/operator manuals, as available from the manufacturer/distributor.

2.2.1 Drive-Master Co., Inc., or Guidosimplex

Drive-Master Co., Inc., of Fairfield, New Jersey, has been in business since 1952 and is the U.S. distributor of the Left Foot Gas Pedal GS 150 manufactured by Guidosimplex of Italy. The GS 150 model is a removable LFAP and has been distributed by Drive-Master for about a year. Drive-Master used to install the now discontinued permanent floor-mounted LFAP from MPD, however, users reported occasional problems with the discontinued MPD LFAP inadvertently bouncing backward toward the driver when transferring from the pedal to the brake. This discontinued MPD model featured an independently mounted pedal stop/guard for the OEM accelerator pedal.

The Drive-Master (Guidosimplex) quick-release GS 150 LFAP can be installed on any type vehicle with automatic transmission. None of the vehicle's existing safety features are modified to install the pedal assembly, which is removed for use by nondisabled drivers. Removal is done by unscrewing a single wing bolt and then lifting the pedal assembly away from the base plate. The all-steel assembly has a spring-loaded return on the right-side pedal actuator. This spring holds the OEM pedal actuator at the returned (off) position and results in a slightly higher effort to actuate the pedal assembly than the effort required to actuate the OEM pedal. A pedal stop/guard

prevents the right foot inadvertently applying the OEM accelerator and prevents the left-side pedal from inadvertently falling backward when the foot is removed from it.

The installation instruction booklet for the GS 150 was recently revised and includes step-by-step installation instructions. Directions for positioning the roller and actuator arm in relation to the OEM accelerator pedal are provided. A rule of thumb for left-side pedal adjustment is to copy OEM accelerator pedal lateral and height distances as closely as possible. When this is not possible, extra care must be taken to ensure that new pedal distances will not allow the driver's left foot to apply the gas and brake at the same time or to slip off the new pedal and become caught between the gas and brake pedals. The instructions emphasize that the pedal protector is not a foot rest. A warning is provided that this adaptive equipment should only be installed in a vehicle if the end user possesses, for example, an adaptive equipment evaluation from a rehabilitation or driver education centre. The instructions also state that end users who do not have a valid restricted driver's licence should acquire driver training through an approved education program before using this equipment and should possess a valid restricted driver's licence.

Drive-Master does not sell directly to end users, only to dealers in its distribution network. These dealers are N.M.E.D.A. members. When approached by end users, Drive-Master encourages them to seek the guidance of an Occupational Therapist (OT) or rehabilitation specialist. The Drive-Master model GS 150 can be purchased from Canadian dealers for CAN$352. Drive-Master was unable to estimate how many of its GS 150 models are sold in Canada each year.

2.2.2 driving Systems international (dSi), or *Fuji*Auto

Located in Van Nuys, California, driving Systems international is the U.S. distributor of the Left Accelerator Pedal Model LA-2 (also known as the Fujicon) for the manufacturer, *Fuji*Auto of Japan. The LA-2 model is a removable type and has been distributed by dSi for about five years.

The dSi model LA-2 quick-release LFAP can be installed in all types of vehicles with automatic transmissions. Being strictly a mechanical device, none of the vehicle's existing safety features are modified to install the pedal assembly, which is removed for use by nondisabled drivers by pulling the pedal stop/guard horizontally toward the driver's door and rotating the pedal assembly vertically to slide it off the permanently mounted base plate. The left-side pedal is designed to be narrow at the base so that it can be positioned at the same distance from the brake pedal as the OEM accelerator pedal. The left-side pedal pad pivot is spring-loaded, which is intended to provide a good fit between the driver's left foot and left-side pedal pad, and to reduce driver fatigue. A right-side pedal stop/guard is provided to block unintentional operation of the OEM accelerator pedal and to prevent the left-side pedal from inadvertently falling

backward when the foot is removed from it. The device comes with a warning decal to be placed in a conspicuous location on the dashboard to indicate that the vehicle is equipped with an LFAP, which is to be operated only by a trained driver.

The *Owners & Installation Manual* for the dSi model LA-2 includes step-by-step installation instructions, guidelines for safety and maintenance, operating instructions, inspection instructions following installation, and instructions for use. Directions for positioning the accelerator stop/guard, roller, and actuator arm in relation to the OEM accelerator pedal are provided, illustrating both correct and incorrect installations. An illustration shows that the distance between the left-side pedal and the brake must be equal to the distance between the brake and the OEM accelerator pedal. The height of the left-side pedal should be similar to that of the OEM accelerator pedal when installed correctly. Adequate clearance must be provided to be able to activate the emergency brake completely without interfering with the left-side pedal. The instructions state that routine maintenance and cleaning of the device is required to ensure optimum performance with maintenance inspections recommended at least every six months. The instructions stress that the pedal stop/guard is not to be used as a foot rest. They also provide requirements for inspecting the device following installation as well as descriptions of its features and the quick release removal and installation procedures. The manual emphasizes that this driving device is to be used exclusively by a trained driver and that the LA-2 must be removed before any other driver operates the vehicle.

dSi does not sell directly to end users, only to mobility equipment dealers in its distribution network. These dealers are N.M.E.D.A. members. When approached by customers directly, dSi encourages them to consult a physician, OT and/or driver rehabilitation specialist to select the right product and provide them with the necessary training. The dSi model LA-2 can be purchased from Canadian dealers for US$350 installed. dSi estimated that fewer than 50 units are sold annually in Canada.

2.2.3 Howell Ventures Ltd.

Howell Ventures Ltd. of Upper Kingsclear, New Brunswick, has manufactured and distributed the Sure Foot left foot accelerator pedal for approximately three years. The Sure Foot model is a permanent type LFAP.

Howell Ventures has not encountered any automatic vehicle that could not accommodate the Sure Foot. None of the vehicle's existing safety features are modified to install the pedal assembly. The Sure Foot left-side pedal and right-side pedal actuator are flipped backward onto the floor to allow nondisabled drivers to operate the vehicle. There is no pedal stop/guard, return spring or other mechanism to prevent the left-side pedal from inadvertently falling backward or to prevent the right foot from inadvertently applying the OEM accelerator.

A single page of installation instructions for the Sure Foot provides basic installation guidelines. An illustration shows the roller on the OEM pedal but dimensions for positioning the roller and actuator arm in relation to the OEM accelerator pedal and for the left-side pedal adjustment are not provided. The instructions caution that the roller should be positioned so it will not slip off either end of the existing OEM pedal. The instructions do not, however, indicate that the device should be operated by trained drivers only, nor do they indicate that the left-side pedal and actuator arm should be flipped backward to permit operation by nondisabled drivers.

Howell Ventures does not sell directly to end users and has dealers in Canada and the U.S. listed on its Web site. The Sure Foot retails at CAN$100. Howell Ventures typically sells 75 units a year in Canada and noted that there had been an increase in Sure Foot sales in the past months, since MPD discontinued sales of its permanent type LFAP in the spring of 2000. Given that many of its customers prefer the permanently mounted type over the removable type, and with MPD discontinuing sales of its product, Howell Ventures surmizes that Sure Foot is able to capture this market.

2.2.4 Mobility Products and Design (MPD), or Braun/Crow River Inc.

Mobility Products and Design (MPD) of Brooten, Minnesota, is a member of the Braun family of companies. In 1986, Braun bought Crow River, which resulted in the acquisition of MPD. In April 2000, MPD discontinued sales of its permanently mounted left foot accelerator pedal, model 3540R, which had been manufactured and distributed since 1986. At present, MPD manufactures and distributes a removable type left foot accelerator pedal, model 3545.

According to MPD, model 3545 can be installed on any type of vehicle with an automatic transmission, except those with moveable brake and accelerator pedals. None of the vehicle's existing safety features are modified to install the pedal assembly. The LFAP is equipped with a pedal stop/guard to prevent inadvertent application of the OEM accelerator pedal. MPD warns that the pedal stop/guard is not to be used as a foot rest. If someone other than the trained driver is using the vehicle, the LFAP is removed by lifting and holding a key ring and sliding the assembly out of the base plate. The procedure for removal and replacement is illustrated on the pedal stop/guard. Model 3545 also comes with a decal to be placed on the dashboard (so it can be clearly viewed from the driver's position) to indicate that the vehicle is equipped with an LFAP, which is to be operated by trained drivers only.

The *Installation and Owners Manual* for the MPD model 3545 includes step-by-step installation instructions, post installation inspection instructions, guidelines for safety and maintenance, and operating instructions. Directions for positioning the accelerator stop/guard, roller and actuator arm in relation to the OEM accelerator pedal are provided, illustrating both correct and incorrect installations. An illustration shows that

the distance between the left-side pedal and the brake is to be equal to the distance between the brake and the OEM accelerator pedal. A warning states that if it is not possible to make these dimensions equal, DO NOT use the LFAP in this vehicle. Adequate clearance must be provided to be able to activate the emergency brake completely without interfering with the left-side pedal. The instructions state that regular maintenance and cleaning of the device is required to ensure optimum performance. Maintenance inspections are recommended every three months and a maintenance log is provided for this purpose. The instructions stress that the pedal stop/guard is not to be used as a foot rest. They also provide requirements for inspecting the device following installation. A warning indicates that improper adjustment or installation of the LFAP may result in the OEM pedal being locked in the partial or full activation position. The instructions describe the features of the device as well as the quick release removal and installation procedures. The manual emphasizes that drivers must not operate a vehicle with this device installed until properly trained by a certified driver rehabilitation specialist and licensed appropriately. The LFAP assembly must be removed if someone other than a trained driver is operating the vehicle.

MPD does not sell directly to end users, only to mobility equipment dealers in its distribution network. MPD encourages end users to seek the prescription of a physician or OT. The MPD model 3545 can be purchased from Canadian dealers for CAN$310. MPD was unable to estimate how many of its LFAP model 3545 are sold in Canada each year.

2.2.5 Manufacturing and Production Services Corporation (MPS)

Oakhill-Labron Mobility in Richmond, British Columbia (established in 1982), is the sole Canadian distributor for the LFAP manufactured by Manufacturing and Production Services Corporation (MPS) of San Diego, California. MPS directs all questions from Canadian customers to its Canadian distributor. The Left Foot Accelerator manufactured by MPS is a removable type and has been on the market for more than two years.

According to Oakhill-Labron, the MPS model can be installed on any type of vehicle with an automatic transmission. None of the vehicle's existing safety features are modified to install the pedal assembly, which is removed for use by nondisabled drivers by pressing the red release button on the central pivot block and lifting the pedal assembly off the base plate. A stop in the form of a collar on the horizontal rod prevents the left-side pedal from inadvertently falling backward when the foot is removed from the accelerator pedal. No pedal stop/guard is provided to prevent the right foot from inadvertently applying the OEM accelerator.

The *Owner's Manual* for the MPS Left Foot Accelerator includes installation instructions, post installation inspection instructions, and operating instructions. No

dimensions for positioning the roller and actuator arm in relation to the OEM accelerator pedal nor for adjustment of the left-side pedal are provided. The instructions state that the roller is usually positioned at the pivot point or centre of the OEM accelerator pedal. The installer is requested to ensure that the roller cannot roll over the top or off the bottom of the pedal when the OEM accelerator pedal is fully actuated. Adequate clearance between the left-side pedal and the brake pedal must be provided to ensure that the left foot does not apply the brake and accelerator simultaneously. Post-inspection procedures include checking for any binding or interference, and making sure the actuator arm can lift at least 25.4 millimetres high off the gas pedal but cannot fall back over centre toward the driver. The instructions describe the features of the device as well as the quick release removal and installation procedures. The instructions also note that most states and countries require a restrictive driver's licence for persons using such adaptive driving aids, and recommend that persons not familiar with the model acquire professional driver training. They also stress the importance of drivers fully familiarizing themselves with the operation of the device and provide guidelines to be used when practising and learning to drive with the LFAP. If for any reason a driver is not comfortable with the installation of the LFAP, it is recommended to consult the installation dealer.

The MPS unit retails for CDN$225. Oakhill-Labron was unable to estimate the number of units sold in Canada each year.

2.3 Accident and Incident Summary

Various sources were contacted to obtain relevant accident and incident data related specifically to the use of LFAP devices. Most of the documented information was obtained from the Vehicle Controls and Adapted Vehicles Division of the National Highway Traffic Safety Administration (NHTSA), which is the U.S. government agency responsible for improving safety on U.S. highways. The data was reviewed for trends as well as commonality of situations and event types. From accident reports and anecdotal evidence, however, it is difficult to quantify whether LFAPs account for a statistically significant proportion of accidents and incidents involving disabled drivers.

Although there is insufficient evidence to determine the actual cause of these accidents/incidents, the following situations are probable:

- insufficient training and experience using the LFAP;
- installation without prescription that ensures the LFAP is suitable for the driver;
- incorrect installation (particularly insufficient space between left-side pedal and brake, causing the driver to inadvertently apply the wrong pedal or both at the same time); and
- non-removal of the LFAP by the nondisabled driver resulting in the use of the left-side pedal by mistake and/or without adequate training.

There are also incidents that were not caused directly by the LFAP, but because the device was present in the vehicle, the incident is categorized as involving an LFAP.

Pittsburgh Post-Gazette Article

In a newspaper article obtained from NHTSA, in 1995 it was reported that a man had only recently begun driving again after a fall on the job that had left him with limited use of his legs. He had had an LFAP installed in his car, allowing him to drive after months of rehabilitation. His legs were very badly damaged and he relied on two canes to get around after spending months at the hospital. He had only been starting to walk and wore a fibreglass brace on his right leg. It was reported that the man's car suddenly roared down the street, missed a turn, became airborne, and hit three men on the sidewalk, killing one and injuring the two others. There was some confusion in that the car was reported in the article to have been equipped for a paraplegic - a person with no movement in either leg. According to the installer the equipment he put in was an MPD LFAP, which is suitable for a driver using the left leg, but unsuitable for a paraplegic. The article suggested that something may have become caught underneath the device. The actual cause is unknown.

NHTSA Defect Office

Two complaints have been received by the Defect Office:

The first complaint was received in 1989. A man, presumably a right leg amputee, had been driving a car using his left leg for the past 50 years, using a permanently mounted suspended-style LFAP. When he purchased a new car, an LFAP manufactured by Gresham Driving Aids was installed. In his letter, the man reported having trouble differentiating between the gas and brake pedals because they were only 22.23 millimetres apart and lined up on the same level. Because of the wheel-well humps in front-wheel drive cars, the left-side pedal could not be moved any further to the left. When driving in winter, he found this difficulty was compounded when he wore heavy winter boots or galoshes, which made it more difficult to be sure of engaging only one pedal at a time. There was a tendency to step on both the gas and brake pedals at the same time. As a result, he ran into someone because he thought he was stepping on the brake. In addition, the left-side pedal could not be fully depressed for quick passing because the left part of his shoe was held back by the hump. The manufacturer said the only alternative would be to switch to hand-operated controls or to "beat down" the wheel-well hump on the left side. The man expressed his concern that his safety was being compromised using the LFAP installed as it was. In his letter of complaint, he stated that he preferred a suspended-style gas pedal, and that at least 25.4 millimetres

had to be cut off the left side of the existing brake pedal to make more room between pedals.

The second complaint was received in 1993. A woman who had contracted polio earlier in life had been driving for 40 years using her left foot (i.e., brake and OEM accelerator). While selling the woman a new car, the dealer noticed that she drove with her left foot and suggested she use an LFAP, which could be obtained under the vehicle manufacturer's mobility program. The customer agreed to try it. She subsequently picked up the car from the dealer and, as reported in the letter of complaint, was "very uncomfortable with the left accelerator" and drove the new car home, "most of the time using the right accelerator" as she had always done. The next morning, as the woman was applying the brake to park the car in front of a store, the car lurched forward, seriously injuring a person exiting the store. The woman expressed her concern that the LFAP was defectively designed. From the correspondence, it is not known which LFAP model was installed.

NHTSA's DOT Auto Safety Hotline

NHTSA's DOT Auto Safety Hotline at 1-888-DASH-2-DOT (also available through the NHTSA Web site at www.nhtsa.dot.gov/cars/problems/ivoq/default.htm) encourages people to contact NHTSA to report a vehicle safety problem. The report is entered into NHTSA's vehicle owner's complaint database and is used with other reports to determine if a safety-related defect trend exists. NHTSA looked in the database under the code Adaptive Accelerator/Brake Systems and reported that there were no complaints concerning LFAPs. NHTSA cautioned, however, that it doesn't necessarily mean they do not exist. There is no screening code in the database for this particular equipment, therefore finding complaints would be very difficult.

NHTSA Adaptive Equipment Questionnaire

The Adaptive Equipment Questionnaire available on the NHTSA Web site at www.nhtsa.dot.gov/feedback/adaptive.html encourages people to contact NHTSA and cite their experiences with adaptive equipment and modified vehicles to guide NHTSA's research projects and help NHTSA identify areas where people may be having problems. Of the 158 responses received to date, NHTSA has had six that relate to an LFAP: four installed in cars, one in a pickup and one in a minivan.

- Two persons (1 car, 1 minivan) rated safety 5 out of 5. The minivan driver also indicated installation of hand controls, so NHTSA was not sure which devices may have been installed in this vehicle.
- One person with a car rated safety 4 out 5.
- The person with the pickup rated safety 3 out of 5 and stated that more control was needed over braking (again, NHTSA was unsure how this

related to the LFAP, but that was the only item of additional information in this report).

- The fourth person with a car rated safety 1 out of 5 because of an accident that had occurred. The text of the complaint reads: "The pedal is too long and there is not enough room between the brake and the pedal and sometimes you hit both at the same time, especially if you wear running sneakers. I was in a severe accident due to this and my car ended up running over me 3 times as I was evacuated from the driver's side due to the impact. I don't feel safe now and so I want to get hand controls but I want someone who knows what they are doing like in City Island, NY."

NHTSA Crash Investigations Web Site and Special Report

NHTSA is authorized by Congress to collect information on motor vehicle crashes to aid in the development, implementation and evaluation of motor vehicle and highway safety countermeasures. Through the National Automotive Sampling System, two cases were found related to the LFAP. One incident recorded in 1997 (Case file 1997-009-019) involved an LFAP. Vehicle #1 struck Vehicle #2 from the rear when Vehicle #2 made a U-turn into the lane of Vehicle #1. Vehicle #1 was equipped with adaptive driving equipment. From the photographs, the device was an LFAP. The report states that the accident was not caused by component failure.

The second case involved the on-site investigation of a 1991 car that was equipped with an adaptive control LFAP (Calspan Case No. 94-26). The driver was an 85-year-old nondisabled woman. The adaptive control was installed in the vehicle for her husband, who was a right leg amputee. Although the device was detachable from the floor of the vehicle, the woman could not remove it and drove the vehicle with accelerator pedals on each side of the brake pedal. When she attempted to exit a driveway and initiate a right turn onto a two-lane local street, she inadvertently depressed the adaptive control with her left foot, which caused the vehicle to accelerate across the road.

Other Sources

Other sources of incidental and anecdotal information related to LFAPs were investigated.

- A U.S. amputee centre chat line had references to persons using their left feet to operate the brake and the OEM accelerator. One person who opted to use an LFAP found using the OEM accelerator uncomfortable on long drives. Another person did not advocate the use of the LFAP because it was too restrictive, limiting the driver to only the particular modified vehicle. This person said he would therefore continue to drive with the left foot using the OEM pedal.

- Discussions with the Ontario Ministry of Transportation revealed that there were no statistics or data available related to accidents involving adaptive aids such as the LFAP.
- Discussions with the Transport Canada Defect Investigation and Recalls Group revealed that there are no records of complaints related to LFAPs in its database.
- A well-known manufacturer of automotive driving aids found that in his experience with LFAPs, the devices do not fail for the most part. Typically, the people using them have been driving for many years using conventional OEM pedals and thus must learn new driving techniques to operate the LFAP. He also stated that the LFAP is commonly prescribed for people who have suffered strokes or other brain-affecting disabilities that affect cognitive abilities. These disabilities must be dealt with in addition to having to learn new skills to perform functions previously handled by the right side of the body. He believes problems related to LFAPs are ones of "human factors" and adaptation, not design deficiencies.
- A representative installer in the Toronto area believes that the LFAP is the most dangerous driving aid today if the installer is careless or ignorant of the correct methods for installation, which need to address both the needs of the disabled and the nondisabled driver. He also commented that the removable type of LFAP does not provide drivers with the desired independence because the pedal assembly is designed for removal/replacement by a nondisabled person.
- Discussions with OTs and rehabilitation specialists revealed one recent accident in Nova Scotia, where a driver using an LFAP was involved in an accident in a parking lot resulting in damage to three vehicles. However, no personal injury was sustained.

3 REVIEW OF EXISTING STANDARDS AND GUIDELINES

A search was conducted for existing standards and/or guidelines related to LFAPs.

3.1 Canadian Motor Vehicle Safety Act

The Canadian Motor Vehicle Safety Act (MVSA) incorporates the Canadian Motor Vehicle Safety Standards (CMVSS) that are directly applicable to modifications performed on OEM vehicle control systems. The standards apply not only to new vehicles but also to vehicles that were purchased with the intent of modifying them for use by a driver with disabilities. The standards do not, however, apply to pre-owned vehicles converted for a driver with disabilities. Section 3.1.1 summarizes the requirements specified in the CMVSS standards applicable to the installation of LFAPs.

3.1.1 Applicable Standards

CMVSS 101 — Location and Identification of Controls and Displays

The following controls and components, where fitted on a vehicle, shall be fitted in such a manner that they are operable by the driver while the driver is seated in the driver's designated seating position with the driver's seat belt fastened around the driver in accordance with the manufacturer's instructions:

- the accelerator;
- the service brake pedal or lever.

NOTE: Another 20+ controls and components that do not pertain to this study are also referenced in this standard.

Generally, the extra effort required to follow the above specifications should not be extensive as the accessibility of controls is one of the aims of modifying a vehicle for a person with a disability. One potential difficulty in meeting these requirements is the space available to provide adequate clearance between the left-side pedal and other vehicle controls. Another potential difficulty is that OEM driver controls in some vehicles (e.g., the brake) may be biased to right-leg operation by having the brake pedal to the right of the driver's centre.

CMVSS 124 — Accelerator Control Systems

The throttle of every vehicle shall return to the idle position from any accelerator position within the applicable time limit specified below:

- 1 second for vehicles of 10,000 pounds (4 536 kilograms) or less Gross Vehicle Weight Rating (GVWR); and

- 2 seconds for vehicles of more than10,000 pounds (4 536 kilograms) GVWR.

The LFAP actuates the OEM accelerator to which this standard applies. The concern related to the LFAP is that the device must not adversely impact the operation of the OEM accelerator as related to this standard.

3.1.2 Enforcement of CMVSS Compliance

The Enforcement Branch of Transport Canada's Road Safety Directorate does not normally require performance testing of a vehicle in which an LFAP has been installed. The current approach is to examine the installed system and modifications performed on the vehicle to ascertain whether the OEM vehicle certification has been affected. Dealers/installers are encouraged to contact the OEM for information on the required modifications. Installed adaptive control systems that are assessed as being quickly removable and that retain the OEM systems after removal are not currently inspected with the aim of enforcing compliance with CMVSS standards. This is based on a clause in the standard which excludes "removable" components not permanently installed.

Aside from enforcing compliance, there are areas of the MVSA that lack standards specifically oriented to ensuring that vehicles modified by the installation of LFAPs meet specific performance and safety requirements. For example, a CMVSS standard specifically referencing pedal location and driver positioning criteria is not included in the MVSA. Therefore, performance of an LFAP cannot be measured and evaluated against a set of standard requirements.

3.2 Canadian Standards Association

The CSA does not currently have a standard that is applicable to LFAPs because there is neither a strong enough market in Canada for LFAPs nor a compelling reason (e.g., reported problems with the safety of the devices) to warrant spending time and resources to develop a CSA standard specific to LFAPs.

The standard Z323.1.2-94 entitled *Automotive Adaptive Driving Controls (AADC) for Persons with Physical Disabilities* specifies performance requirements for manual adaptive controls that allow vehicles to be driven by persons with physical disabilities. The main objective of the standard is to minimize as far as possible the hazards associated with these devices arising from their design, quality of manufacture, installation and use. The standard is based on SAE's Recommended Guideline J1903 and Australian Standards documents AS 3954.1-1991 and AS 3954.2-1991. Although standard Z323.1.2-94 does not apply to LFAPs, it may provide useful guidance in the development of a standard for LFAPs.

3.3 Driver Licensing Regulations

Driver licensing requirements vary from one province/territory to another. The Driver Improvement Office of the Ontario Ministry of Transportation stated that in cases where the ministry is notified (by a doctor, OT or rehabilitation specialist) that an individual requires an LFAP to operate a motor vehicle, a review of all documents on the individual's file is undertaken. Based on the Ministry review, the individual may be requested to undergo a retest, which in turn results in a code 9 being added to the driver's licence. A code 9 is a restricted licence, in this case requiring the driver to use an LFAP when driving a motor vehicle. The testing conducted by the Ministry, including its evaluation methods and pass/fail criteria, is the same for drivers using the LFAP as for nondisabled drivers using the OEM accelerator pedal.

3.4 Other Standards and Guidelines

A number of voluntary standards and guidelines exist that are relevant to LFAPs.

3.4.1 N.M.E.D.A.

The National Mobility Equipment Dealers Association was incorporated in Florida in 1987. N.M.E.D.A. received national status in 1988 with its mandate to assist dealers and manufacturers of adaptive equipment in transportation for the disabled. During the next two years, a set of guidelines was drawn up on proper installation of equipment used by the disabled community, which its members follow. Membership is voluntary and consists of automobile manufacturers, adaptive equipment suppliers, driver evaluator/trainers for the disabled, doctors, lawyers, insurance adjusters, government officials from the U.S., Canada and England, and other professionals and consumers interested and/or involved in the mobility needs of the disabled.

The *N.M.E.D.A. Guideline* (revised 12/22/99) provides recommended practices and is available from its Web site at www.homestead.com/nmeda/PUBLICATIONS.html. N.M.E.D.A. points out that federal and state laws as well as manufacturer's installation procedures supersede these N.M.E.D.A. Guidelines: "The more stringent will prevail." Section 29.1 pertains to the LFAP:

> 29.1A Left foot accelerator must be easily disengaged (or removed), without the use of tools, for ease of use of OEM pedals by an able-bodied driver. Method of disengagement must not compromise the safety of the left foot accelerator.
>
> 29.1B Left foot accelerator shall be installed only in vehicles with automatic transmission.

29.1C Spacing between left foot accelerator and brake pedal shall be sufficient to avoid inadvertent use of the wrong pedal (spacing between OEM pedals is a good guide). Left foot accelerator should never be on the same plane or higher than the brake pedal. There shall be no interference when the left foot accelerator is fully depressed.

29.1D Thorough inspection of the underside of a vehicle shall take place prior to drilling, or mechanically fastening, to avoid contact with fuel lines, brake lines, wiring, etc. Fasteners shall not rub or chafe any wiring, fuel or brake lines. (Construction and use of templates for hole locations, cutouts, etc. that avoid OEM components are encouraged.)

29.1E Padding and insulation shall be removed in order to achieve the manufacturer's torque specification and the proper fastener clamp load for the left foot accelerator to the floor.

29.1F Left foot accelerator shall be installed in such a manner that, during use by a disabled driver it cannot fall backward or otherwise become disengaged rendering it inoperative.

29.1G Left foot accelerator must not bend and must provide smooth acceleration equivalent to OEM operation and performance.

29.1H Install all warning or instructional labels supplied by the manufacturer in a manner consistent with the manufacturer's installation instruction.

29.1I Test drive vehicle and recommend client test drive in a low traffic environment prior to daily use.

29.1J Give client the owner's manual and operating instructions as supplied by the manufacturer and complete warranty card.

Section 29.1 also refers to Section 0.00 for applicable general "Best Practices", which provides additional instructions for the installer including following the manufacturer's requirements and instructions, and other installers' general practices.

The guidelines address the general issues associated with LFAPs; however, they do not provide technical details for the design and installation of these devices.

The voluntary Quality Assurance Program (QAP), initiated by N.M.E.D.A., represents an example of the motor vehicle conversion industry attempting to regulate itself through the use of standards, guidelines, recommended practices and certification.

The requirements to be certified under N.M.E.D.A.'s QAP include the following, which are taken from the report entitled *Persons with Disabilities and Converted Vehicle* (TP 13019E) prepared for Transport Canada's Transportation Development Centre by Goss Gilroy Inc. Individual installers/dealers must:

- follow specific guidelines when performing modifications;
- have a certified automotive welder on staff;
- have a individual on staff who is trained and certified in dealing with assistive components for vehicles;
- have a knowledgeable person on staff responsible for quality control;
- agree to a review of payroll information to verify that the individuals identified as being certified are in fact involved in vehicle modifications;
- have a minimum of one million dollars product liability insurance;
- agree to two mandatory site inspections each year (either announced or unannounced) where the company's facilities and products are inspected by an independent engineering firm.

Because of the voluntary nature of the program and the absence of a requirement to comply with FMVSS and CMVSS requirements, the QAP is viewed as an industry quality control program as opposed to compliance to regulations.

N.M.E.D.A., in general, is advancing toward a proactive approach to incorporating applicable standards and guidelines as they become available. However, N.M.E.D.A. is an industry association for which membership is voluntary, thus principles and guidelines propagated by N.M.E.D.A. may not be assumed to be adhered to throughout the industry by either manufacturers or installers.

3.4.2 SAE

The Society of Automotive Engineers (SAE) is a one-stop resource for technical information and expertise used in designing, building, maintaining and operating self-propelled vehicles for use on land or sea, in air or space. SAE's membership consists of engineers, business executives and educators from 97 countries who share information and exchange ideas for advancing the engineering of mobility systems.

According to the chairman of the SAE Adaptive Devices Committee (ADC), there have been concerns for some time about LFAPs. These concerns relate to:

- education at all levels in the process (e.g., prescription, manufacture, installation and use);
- manufacturer/installer related issues such as design, installation, functionality and quality; and
- use of the devices by nondisabled drivers (e.g., using the vehicle not realizing, or ignoring that the LFAP is installed).

In February 2000 the SAE ADC established an LFAP sub-committee, whose purpose is to eventually draft a standard for LFAPs. The next LFAP sub-committee meeting will likely be at the February 2001 N.M.E.D.A. conference in Daytona, Florida.

Three SAE standards are relevant to this study:

Vehicle and Control Modifications for Drivers with Physical Disabilities Terminology

SAE J2094 provides the terminology and associated definitions for vehicle and control modifications, including the LFAP, whose definition is provided in the Glossary and in Section 2.1 of this report.

Automotive Adaptive Driver Controls Manual

SAE J1903 establishes a uniform procedure for assuring the manufactured quality, installed utility, and service performance of certain automotive adaptive products, other than those provided by the vehicle manufacturer, intended to provide driving capability to persons with physical disabilities. These devices function as adaptive appliances to compensate for lost or reduced performance in the arms or legs, or both, of the driver. Some of the devices are designed to transfer foot functions to the hands, hand functions to the feet, or functions from one side of the body to the other. Although this procedure does not apply to LFAPs directly, it may provide useful guidance in the development of a standard for LFAPs.

Motor Vehicle Dimensions

SAE J1100 is a recommended practice that defines a uniform set of definitions for interior and exterior dimensions for passenger cars, multipurpose passenger vehicles, and trucks. While SAE J1100 does not provide specific dimensions to guide design, it does offer a standard reference measurement system that allows all manufacturers to report the actual measured lengths and displacements for each vehicle manufactured. This provides meaningful vehicle-to-vehicle comparisons such as driver head room, truck luggage capacity, etc.

Excerpted Sections 3.11 through 3.16 are references from SAE J1100 that relate to the driver's seating position and the accelerator pedal.

> 3.11 H-Point —The H-Point is the Pivot Center of the torso and thigh on the Two- or Three-Dimensional devices used in defining and measuring vehicle seating accommodation (see SAE J826).

3.11.1 Design H-Point —The Design H-Point is located on a drawing by the H-Point on the two-dimensional drafting template placed in any designated seating position. If the designated seating position can be adjusted, the path of the Design H-Point through the full seat adjustment establishes the Design H-Point travel path, and can be dimensionally described by coordinates relative to the three-dimensional reference system.

3.11.2 Seating Reference Point (SgRP) —The manufacturer's design reference point is a unique Design H-Point which:

a. establishes the rearmost normal design driving or riding position of each designated seating position which includes consideration of all modes of adjustment, horizontal, vertical, and tilt, in a vehicle,
b. has X, Y, Z coordinates established relative to the designed vehicle structure,
c. simulates the position of the pivot centre of the human torso and thigh, and
d. is the reference point employed to position the two-dimensional drafting template with the 95th percentile leg described in SAE J826.

3.11.3 Actual H-Point —The actual H-Point is located in an actual vehicle by the H-Point on the three-dimensional H-Point Machine with the 95th percentile leg installed in any designated seating position per instruction in SAE J826 and can be dimensionally located by coordinates relative to the three-dimensional reference system.

3.12 Designated Seating Position—Any plan view location intended by the manufacturer to provide seating accommodation while the vehicle is in motion, for a person at least as large as a 5th percentile adult female, except auxiliary seating accommodations such as temporary or folding jump seats.

3.13 D-Point— D-Point is the lowest point on the buttocks contour of the seated Two- or Three-Dimensional Device in the installed position.

3.16 Foot Pedal References— (See Figure 2 - Reference Points).

3.16.1 Accelerator Heel Point (AHP)—The lowest point at the intersection of the manikin heel and the depressed floor covering with the shoe on the undepressed accelerator pedal. The foot angle (L46) is at a minimum of 87 degrees with the manikin H-Point at the SgRP. For vehicles with SgRP to heel vertical (H30) greater than 405 millimetres, the accelerator pedal may be depressed as specified by the manufacturer. If the depressed pedal is used, the foot must be flat on the accelerator pedal.

3.16.2 Ball of Foot (BOF)—A point on a straight line tangent to the bottom of the manikin's shoe in side-view 203 millimetres from the AHP. The lateral (Y coordinate) location for the BOF is mid-width on the shoe at the side view BOF location. *
(*Author's Note: this fixed dimension of 203 millimetres is a reference point for consistent dimensioning of other variables and not a recommended pedal location. This dimension is based on the leg and thigh dimensions of a 95th percentile male manikin and, thus, is a much longer measurement than that of the majority of the population and the individual driver. Refer to SAE J826, two dimensional H-point machine.)

3.16.3 Accelerator foot plane (AFP)—A plane passing through the AHP and the BOF that is normal to the Y plane.

SAE J1100 does not provide specific dimensioning information that can be used for installation of LFAPs, but may be useful in determining whether specific vehicle models have the required foot space by reviewing manufacturers' reported measurements using the reference standard. Reference dimensions from this standard may be useful in helping to establish standards or guidelines for installation of LFAPs.

3.4.3 Human Engineering Guide for Design

According to the Ergonomics Division of Road Safety and Motor Vehicle Regulation, Transport Canada, there are guidelines for the configuration of foot pedals, taken from *Human Engineering Guide to Equipment Design* (sponsored by Joint Army-Navy-Air Steering Committee, John Wiley & Sons, 1972).

The following parameters are indicated for a mock-up of a road vehicle driver position (for 5th to 95th percentile operators):

- the minimum accelerator operation rest position is 28 degrees, measured from the toe of the accelerator to a horizontal plane;
- the centre of the accelerator measures 127.0 to 177.8 millimetres from the centreline driver's position;
- the edge of the toe of the accelerator measures 50.8 millimetres from the edge of the brake pedal;
- the toe of the accelerator pedal is angled outward (i.e., to the right) at 10 degrees;
- the accelerator downward travel from the normal accelerator operating position is 15 degrees;
- the accelerator size is 50.8 x 228.6 millimetres minimum; and
- the minimum force to depress the accelerator pedal is 4.54 kilograms.

These dimensions are suited for heavy equipment such as construction and logging machinery. When these dimensions are compared to those of modern passenger motor vehicles, it is noted that the available space on the driver's floor does not accommodate these dimensions. Generally, passenger motor vehicles built since the *Human Engineer Guide to Equipment Design* was published do not conform to the parameters in this publication.

3.4.4 Great Britain

The British publication, *Guidelines on the Adaptation of Car Controls for Disabled People*, prepared by the Automobile Division of the Institution of Mechanical Engineers, London, England, 1990, provides guidelines to help the many garages or individuals who are occasionally asked to make conversions but who may not have much experience in this specialized field.

Section 1 of the guideline states that the publication is a collection of information on best practices in a form that can be used easily by those directly concerned with the conversion of vehicles for disabled people.

Section 2 concentrates on ergonomic and functional requirements of the modifications, including matching controls to the driver's needs, measuring the driver, examining the range of adjustment needed for the disabled driver and remembering the need for use by other drivers. The guidelines in this section provide an excellent example of the types of ergonomic issues that should be considered in any future development of a standard/guideline for LFAPs. For example, the guidelines state that, if the controls are radically different from those of conventional cars, a warning notice should be placed where it is clearly visible. "This is particularly important if a left foot accelerator pedal is has been fitted, as the functions of the two pedals are not immediately apparent." In addition, conditions relating to operating forces are specified in terms of the maximum force acceptable to operate foot pedals. For example, when the "accelerator is operated continuously ... the force required should be limited to 10 percent of the persons [sic] maximum strength while operating that control, i.e., measured in the actual location and direction of operation." This may be useful to the OT in the prescription process, as the OT would be able to measure the leg/ankle strength of the potential user and compare the results to the force required to depress the left-side pedal.

Section 3 of the guideline describes issues to consider to avoid damaging the original vehicle by the conversion, such as implications with regard to the OEM warranty, potential damage to the vehicle, potential unsafe situations for the driver, and considerations in the transfer of conversions from one vehicle to another. This section also describes general requirements for electrical and mechanical control systems.

Section 4 offers an overview of vehicle construction regulations that are applicable in the U.K. to vehicle conversions for disabled drivers. It states that vehicle modifiers have a responsibility to be familiar with the requirements of these regulations before they undertake the conversion or modification of a vehicle for the safety of both the driver and others on the road as well as for their own legal protection.

Section 5 provides specific requirements and design details of a variety of adaptive controls. Section 5.5, *Left Foot Accelerator Pedal* is relevant to this study and is transcribed below:

> "[An LFAP] is required by drivers who cannot or have been advised not to use their right leg, but who have a good left leg. The left foot accelerator pedal is a device to operate the existing throttle pedal with the left foot. Three types are in common use:
>
> i) a left 'short' pedal is fitted, and the right pedal is modified so that its lower part is easily detachable (approximately 130 millimetres) and it can be transferred to the left 'short' pedal providing a left pedal at the same relative position to the brake as the original right pedal. The axis of the left pedal should be in line with the axis of the right pedal. Care should be taken to ensure that any kick down switch can still be operated.
> ii) a left pedal is fitted with the capability of being folded up. The right pedal is modified the same way and an inter-connecting cable fitted. In this arrangement one pedal is always folded up and the action of folding it down automatically retracts the other pedal. Thus it is impossible to have both pedals either up or down together. The cable is only used for the folding up action and does not operate the control as such.
> iii) a left hand pedal pivoted from the floor is connected by a cross-axle assembly to a lever which operates the right hand pedal. The pedal folds back on the floor of the car when not required. Experience has shown that when both right and left foot accelerators can be in position simultaneously, it can cause confusion for an able bodied person, whether a relative, friend or garage mechanic. In addition many drivers who use a left foot accelerator require the space on the right side for their stiff leg, artificial leg, etc.
>
> In all cases these devices must be securely fixed to the vehicle and be so constructed that neither the car's controls or performance is in any way impaired. They must not bend or give during operation and rotary bearings shall be of adequate dimension to ensure long life.
>
> When deciding which type is most suitable it must be remembered that some drivers may require a clear space for a stiff leg and a pedal guard."

Although Section 6 deals with advanced technology adaptive aids, it also includes basic information on the requirements for manufacturers and installers to test for strength and functionality. It provides the requirements for manufacturers to supply detailed fitting instructions, including diagrams, tightening torques and service information.

Section 7 discusses the need to provide guidance on maintenance issues. "The best engineered conversion will not function properly if it is not maintained."

Appendix 1 of this guideline provides a list of disabled driver assessment centres (or rehabilitation centres) in the U.K.

This British guideline contains a significant amount of information that would be of assistance in developing standards or guidelines for LFAPs in Canada.

3.4.5 Australian Standard

The Australian Standard, *Motor vehicle controls - Adaptive systems for people with disabilities, Part 1: General requirements*, AS 3954.1-1991, states under Section 5:

> "Driving controls shall comply with the following:
>
> [...]
> (c) Where an additional accelerator pedal is fitted to the left of the existing brake or clutch pedals (or both), both the left-hand and the right-hand pedals shall be independently capable of being rendered inoperable."

Although this standard provides only a single clause related to LFAPs, the sections and contents may provide useful guidance in the development of a standard for LFAPs. In particular, it suggests the following issues should be considered: abilities of the user, licensing requirements, appropriate vehicle design and selection, selection of the most suitable driving control device, and driver training.

3.4.6 New Zealand Standard

The New Zealand Standard, *Driving Controls for People with Disabilities, Part 1, Hand Control*, NZS 5832: Part 1: 1988, establishes specific performance requirements for manually operated driving control systems intended for use by people who are physically disabled, to enable them to independently operate motor vehicles. In an appendix describing the development of a fatigue test rig to evaluate driving controls, the recommended design value for the distance between the accelerator and the brake is 100 millimetres, the reaction of the accelerator at maximum travel is 15 kilograms force, and the angular travel of the accelerator is 20 degrees. Although this standard

does not apply to LFAPs, it may provide useful guidance in the development of a standard for LFAPs.

3.4.7 Other Related Organizations

Other organizations such as the Association for Driver Rehabilitation Specialists (ADED) and the Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) were surveyed for information relating to LFAPs. Both organizations provide certification to qualified individuals working in their respective fields, but do not provide specific design or installation guidelines related to LFAPs. ADED supports the Certified Driver Rehabilitation Specialist program and RESNA supports the Assistive Technology Practitioner Certificate and Assistive Technology Supplier Certificate programs.

4 ENGINEERING ASSESSMENT OF DEVICES

4.1 Design

The following elements were considered in the review of the design features and utility of the selected LFAP products available to drivers with disabilities:

- design and manufactured strength of materials and components;
- general design;
- appearance and quality of components and assembly;
- service use overload;
- susceptibility to vibration;
- service life of components and assembly;
- training required to install;
- product labelling and caution labels;
- documentation, installation and operator instructions;
- ease of use;
- required maintenance; and
- operational safety.

The selection of LFAP products assessed according to the above categories is based on the most commonly available LFAPs that are commercially available and installed in Canada.

4.1.1 Design and Manufactured Strength of Materials and Components

Each of the devices was reviewed for appropriateness of materials and manufacturing processes used as they affect the strength of the components of the assemblies. Materials used for the main components include steel, aluminum and plastic. In each case the materials and manufacturing processes were appropriate and provided the required component strength to perform their function without distorting the LFAP or the vehicle interface. The integrity of the individual components does not appear to be a problem. Component interfaces are addressed throughout the rest of this section.

4.1.2 General Design

The Drive-Master LFAP has a very high vertical arm with a relatively small pedal attached at the top. This high height from the floor to the centre of the pedal is closely set to the foot size of a 95 percentile male. The short pedal surface makes it difficult for a smaller foot to reach the pedal when the heel of the foot is in the normal driving position on the floor. This is further discussed in Section 4.1.12.

The Drive-Master device has a return spring on the right-side pedal actuator that returns the pedals in a positive manner when the left foot is releasing the pedal to decelerate or idle. The advantage is that it provides a positive return to the idle position; however, the additional force required by the leg/ankle to depress the pedal may be fatiguing for some drivers or beyond the continuous force capability of others. All other LFAPs use only the OEM accelerator springs to return the assembly to the idle position. It may be appropriate to specify a maximum force required to depress the accelerator fully.

The pedal stop/guard on the Drive-Master, dSi, and MPD LFAPs is permanently attached to the removable portion of the device. The location of the interface of the removable part and the base plate, by necessity, is at a fixed point on the base plate. This results in the base plate necessarily being located such that the stop/guard and right-side pedal actuator are located in a fixed position over the OEM accelerator. Thus the position of the base plate is dictated by the location of the OEM accelerator pedal. Installation problems can occur if this pre-determined position does not allow adequate fastener access, component clearances or flat mounting surfaces. The base plate does provide for several choices of mounting holes, shims and self-tapping fasteners, but still may not overcome the aforementioned installation problems. It is possible for the installer to make decisions to not fully tighten fasteners, use less than the number of specified fasteners, not use the appropriate shims, or use wrong diameter holes for self tapping fasteners, etc. This is inherent in the design and must be addressed in more detail in the installation instructions.

The Howell Ventures permanently mounted LFAP and the MPS removable LFAP (does not come with pedal stop/guard) are fully adjustable along the cross-axle assembly so that the base plate can be positioned at any location between the left-side pedal and the right-side pedal actuator. This reduces the problems mentioned in the previous paragraph but still is not necessarily a full solution to the potential for improper installation. Again, these issues must be more fully addressed in the installation instructions.

Two of the devices, the dSi and the Drive-Master, have a vertical arm on the left-side pedal permanently fixed at 90 degrees to the cross-axle assembly and that cannot be adjusted by rotating the pedal laterally to provide more adjustment options. The MPD and MPS models provide lateral pivoting adjustment of the left-side pedal; however, adjustment to the full amount illustrated in the instructions or as allowed by the adjustment slots can result in distortion of the pedal or in the potential for the pedal to become loose as the returned lip on the formed metal pedal interferes with the full adjustment range. About two-thirds of the indicated adjustment is available. The Howell Ventures device is the only one that allows full lateral rotational adjustment of the left-side pedal.

In all cases, the cross-axle assembly from the right-side pedal actuator to the left-side pedal must be cut off just beyond the left-side pedal final adjustment point in order to

fit any of the LFAPs into many vehicles and to ensure the left-side foot space is not impeded in any vehicle. This requirement appears only in the Drive-Master and MPD instructions, although it applies equally to all models. The ability to transfer the LFAP to a different vehicle after an initial vehicle installation may be limited as adjustment for wider pedal spacing will no longer be available once the cross-axle assembly has been shortened. This cannot be avoided, except by replacing the cross-axle assembly.

Some installers modify fixed LFAPs such as the Howell Ventures device by building one or more brackets to allow the device to be hung from the firewall or steering column of the vehicle when in use, and lifted up and attached to the underside of the dashboard when not in use. These installers claim that this type of motion from above follows the action of the OEM accelerator pedal more faithfully. There are no written instructions or procedures documenting this installation practice in any of the selected manufacturers' manuals.

Installers indicated that they modify LFAP components in a significant number of installations. The most common modification is the bending and reshaping of the right-side pedal actuator to better suit installation in certain vehicles. This option is mentioned in a single-sentence installation tip in the MPS instruction manual. There are no written instructions or procedures documenting this installation practice in any of the other selected manufacturers' manuals.

4.1.3 Appearance and Quality of Components and Assemblies

Each of the LFAPs examined had a level of appearance and quality that was acceptable to the application for which the devices are used. Although all were acceptable, it must be noted that price, as is the norm, has an impact on the level of quality beyond the accepted threshold. In this case, although the Howell Ventures LFAP was at the lower end of the set, this is reflected in its substantially lower price.

4.1.4 Service Use Overload

In all cases, the left-side pedal is held in place on the cross-axle assembly by a set screw or friction clamping device to allow for adjustability when installing the device or transferring it to a replacement vehicle. Only dSi specified a torque for the fasteners/clamping bolts. Drive-Master stated to tighten all fasteners to the maximum, and the other three manufacturers did not mention the tightness of the fasteners for the left-side pedal. In the case of the MPD LFAP, which features a friction clamp action, it was noted that, when tightened to the maximum, the resisting torque generated on the cross-axle assembly reached approximately 6.82 kilograms before the left-side pedal rotated on the cross-axle. This force is easily generated by most people. Rotation of the left-side pedal on the cross-axle assembly could thus occur when applying full accelerator action to the left-side pedal because the right-side pedal may bottom before

the left. Inadequate tightening of these fasteners or an inadequate clamping force generated by the friction clamp can allow the left-side pedal to move toward the floor and rotate around the cross-axle going to the right-side pedal actuator. Thus the OEM accelerator would not be depressed as far as thought. In an immediate situation this could lead to slow or no acceleration of the vehicle. In the longer term it could proceed to the point of not engaging the downshift mechanism and, ultimately, in not moving the OEM accelerator. This may or may not present a safety problem, but certainly would present a malfunction of the device. It may be appropriate to specify a minimum overload force to be applied to the left-side pedal that does not allow it to move on the cross-axle assembly with the right-side pedal actuator held in a fixed position.

Three of the devices, the Drive-Master, dSi and MPD, offered a right-side pedal stop/guard that was intended to prevent actuation of the OEM accelerator by the driver should the weak or disabled leg or prosthesis inadvertently move to this area. A secondary function of the stop/guard is to prevent the left-side pedal from falling back toward the driver upon rapid removal of the foot (spring back). In each case, there was a note in the instructions that this stop/guard was not a footrest. In only one case did the instructions direct the installer to check for contact with the right-side pedal actuator by 'gently' pressing on the stop/guard. It is likely that, because of driver space restrictions, driver comfort and human nature, this stop/guard, at least on occasion, will be used by the driver as a footrest and at times will be heavily loaded. It may be appropriate to specify a minimum acceptable load that will not cause deflections or movement of the stop/guard such that any function of the OEM accelerator is affected. The three models with stops/guards were all removable devices, therefore specified minimum forces may affect the design and tolerances of the attachment/release mechanisms. A right-side pedal stop/guard is also considered in Section 4.1.12.

4.1.5 Susceptibility to Vibration

All the fasteners used with all the LFAPs examined were supplied with locking devices of some type, except for the floor mount self-tapping screws that came with the Howell Ventures product and the optional floor mount self-tapping screws provided with the MPS product. If the fasteners are properly used, the susceptibility to vibration should be minimal for all devices. There are, however, a number of shortcomings in the instructions provided by each manufacturer that leave the potential for problems resulting from improper installation. The dSi instructions specify torque for the left-side pedal retaining screw but do not mention torque for floor bolts or other fasteners, nor do they specify hole sizes. The MPD instructions specify the hole size and torque for the floor hold-down bolts but do not mention torques for the other fasteners. The Howell Ventures instructions provide hole sizes but do not mention any fastener torques/tightness. The MPS instructions specify floor hole size but do not provide fastener specifications for torque/tightness. They do, however, say to re-check fastener tightness after completing installation. The Drive-Master instructions specify floor hole size and stress that all fasteners be tightened to maximum tightness. Based on the

current manufacturers' instructions, there is considerable potential for susceptibility to vibration and fastener loosening.

It may be appropriate to specify that drill diameters/hole sizes be provided and that all fastener torque requirements be stated.

4.1.6 Service Life of Components and Assemblies

All of the LFAPs examined appeared to have components that were appropriate for a lengthy service (i.e., the life of the vehicle or longer) with a few minor exceptions.

The Howell Ventures product had a non-slip covering on the left-side pedal made of closed cell polyurethane that will likely wear through in a shorter time, particularly in the Canadian winter environment.

All the devices had a mix of surface finishes on the different fasteners used and all had some fasteners with black oxide finish. This type of finish is prone to rust in one to two years in the operating environment of the device. The rust will not significantly affect strength but will affect appearance and may make adjustment more difficult, thus discouraging adjustment of the device. It may be appropriate to suggest more resistant fastener finishes such as black zinc. However, as black oxide is a commonly available finish and others such as zinc oxide tend to be special order or require additional processing, these higher environmental resistance fasteners may add to the cost of the devices.

The removable types of LFAPs all have close fitting interface components and could be affected by the environmental conditions in Canada, particularly in seasons when mud, sand, ice, snow, salt and other debris can accumulate on the floor of the vehicle. This can present problems for both removal and re-installation: in the first instance, the accumulation in and around the device could make removal difficult or impossible due to jamming of the release mechanism or the latch interface; in the second instance, the accumulation in and around the attachment base could make the re-attachment of the removable portion either impossible or not properly secure. In the Canadian environment, this accumulation problem could become both a safety issue and a maintenance issue beyond routine scheduled maintenance. There are standards that simulate salt spray, sand and dust, and ice buildup, and state the that device must function following various exposures to these elements. This type of testing is expensive and may be beyond the scope required for these devices; however, as it is felt that these devices may not be able to perform as designed after exposure to the Canadian operating environment for an extended period of time, Military Standard MIL STD 810 and others similar should be reviewed for potential guides to LFAP designers/manufacturers. Recommendations on regular, frequent maintenance, including removing the removable type and cleaning the base and all other

components, particularly during the winter season, may help this issue, especially if highlighted as a safety issue as well as a maintenance issue.

4.1.7 Training Required to Install

The installation of all of the devices was straightforward and required relatively few skills. It is important for the installer to understand the operation of the device and the function of each of the components, such as the right-side pedal actuator roller. It is also important for the installer to be aware of the full consequences of improper installation of each component (e.g., improper installation/location of the right-side pedal actuator may cause the roller to fall off the pedal when the LFAP device is used, which can result in loss of use of the accelerator or, worse, jamming of the accelerator in a high acceleration position). There is currently a wide variety of installers (individuals) in the marketplace ranging from persons with an interest in mechanical devices to certified motor vehicle mechanics to those with motor vehicle training specifically related to adaptive aids. In discussions with installer organizations it was noted that "the manufacturers' instructions are generally adequate, along with common sense and a little ingenuity", and that "an understanding of the user's needs must be considered."

It may be appropriate to have a standard training course that ensures the installer is exposed to subjects such as: reading and interpreting the installation instructions; the importance of fastener torque and drill hole sizes related to fasteners; understanding LFAP operation; appreciating the effects of incorrect component adjustment; general issues related to vehicle modifications; potential problem areas with respect to the function of the LFAP in different vehicles; implications concerning the modification of the manufacturer's device or its components; and an introduction to LFAP user needs and issues.

Such information may be provided by the manufacturer and a "trainer training" program set up so that a representative or senior installer from an installer organization may be trained by the manufacturer. The trained installer would then deliver a training program at the installer organization to ensure adequate training of all on-staff installers.

4.1.8 Product Labelling and Caution Labels

Of the products examined two — the Howell Ventures and Drive-Master models — had no identification markings at all. The dSi product displayed the Fujicon name only. The MPS and MPD models both provided the manufacturer's address and model description, and the MPS product provided a serial number.

Dash-mounted labels warning that an LFAP was installed in the vehicle were included in the MPD and dSi installation packages. The other manufacturers did not provide any labelling for the vehicle.

Of the four removable types, only the MPD LFAP had cautions and instructions on the device itself as to proper removal and re-attachment procedure for the removable portion of the LFAP.

During discussions with installers and users, it was common to hear comments such as "that looks like it might be a [manufacturer's name] model" or "to remove or replace the device is simple after a couple of times" or "...usually just needs common sense...." In one photograph from an NHTSA incident file, a process of elimination was needed to deduce that the installed device was likely manufactured by a particular company.

It may be appropriate to specify that the manufacturer's name and address, and the model name/number appear on the LFAP product. The serial number is less critical due to the small production quantities.

It may also be appropriate to specify a decal be attached to the dashboard or other area to warn other drivers, particularly those not routinely familiar with the driver and the vehicle (e.g., mechanics, casual drivers of the vehicle, parking attendants, towing operators and others) that the vehicle has been modified for special needs.

Labelling on the device or on the dashboard providing instructions for the removal/disengagement of the device for the above-mentioned drivers should be considered. This would help to reduce the potential for persons unfamiliar with the device to operate the vehicle without being aware of the installation or to use the device when not properly trained to do so.

4.1.9 Documentation: Installation and Operator Instructions

As discussed in Sections 2.2 and 4.2.4, the documentation provided by the manufacturers, including installation and operator instructions, varies in quality, content and volume. Not one set of data provided by any manufacturer fully and accurately addresses the installation or operating issues presented in this report. As shown in Section 4.1, there is a major shortfall in the information presented to installers and drivers.

It may be appropriate to specify a detailed table of contents and general format for this information to help manufacturers, installers and drivers to fully understand, correctly install and use the devices. For example, suggested contents for installation instructions may include: full parts list and illustrations; list of tools required; vehicle preparation required; table of fasteners and torques required; detailed step-by-step instructions for each action necessary; details of hole sizes to be drilled; detailed

checkout procedures; etc. Much of this table of contents could be generated by combining the manuals from each manufacturer, reviewing for shortfalls, and adding missing information as noted in this report and as identified by an industry committee.

A similar process could be used for operating instructions and other data deemed necessary to fully educate all stakeholders. The resulting best practices table of contents and format could then be used as a guide by each manufacturer to produce documentation customized to its specific product.

4.1.10 Ease of Use

In all cases, except for the Drive-Master left-side pedal size, height and possibly the spring return mentioned in Section 4.1.1, a properly installed LFAP is easy for the driver to use. The appropriate OT evaluation, driver training and licensing must be observed to ensure the driver is using the appropriate device and using it properly.

Removal and re-attachment of the removable LFAP assemblies may be a challenge for first-time or infrequent users as instructions are generally lacking in detail. Repeat users will generally become proficient in these procedures.

4.1.11 Required Maintenance

The specified maintenance requirements ranged from none, for the Howell Ventures Drive-Master and MPS devices, to detailed MPD instructions, which specify a three-month clean and lubricate cycle, and a six-month dealer inspection cycle. The MPD manual also includes a maintenance log for the user. The dSi manual recommends a six month inspection and adjustment cycle.

Based on comments from Section 4.1.6, frequent checks of the LFAP installation will be required to ensure safe operation. Wear and deterioration of vehicle components due to environmental causes may not be directly detectable during driving, which will necessitate having the assembly mechanically inspected on a more frequent basis. When other issues such as climate conditions and the extra needs of the driver are considered, a lack of regular maintenance could have more serious consequences.

4.1.12 Operational Safety

When reviewing the design and functionality of the LFAPs, a number of conditions arose that could result in operational safety issues. Although some of the following conditions may not lead directly to a dangerous situation, the confusion resulting from the malfunction adds to the mental workload of a driver already operating a vehicle in an unfamiliar state. Depending on the driver's experience, age, driving skills and

cognitive-motor capabilities, such situations could lead to unsafe conditions for the driver, passengers and other road users.

Fasteners incorrectly torqued or installed, holes too large, and self-tapping screws installed in incorrectly sized holes could cause the entire assembly to move or shift, allowing component parts to jam accelerators in a non-idle condition or allowing components to lodge under the brake pedal assembly and prevent it form being properly applied.

The left-side pedal slippage at the friction surface of the cross-axle assembly, as discussed in Section 4.1.4, may result in the inability to accelerate rapidly in a passing or emergency situation.

Improper accelerator actuator roller adjustment, as discussed in Section 4.1.7, may cause the roller to roll off the top or bottom of the right-side OEM accelerator pedal and this action may jam the accelerator in a non-idle position on certain designs of OEM accelerator pedal.

Right-side pedal stops/guards are either not part of the LFAP assembly or specified by the manufacturer not to be used as footrests. As stated in Section 4.1.4, these devices will be used as footrests despite any such warnings. Each LFAP should come with a right-side pedal stop/guard to prevent a disabled right leg or prosthesis from slipping or jamming in such a way as to force the accelerator pedal downward. A guard would also make the nondisabled driver aware of the existence of a non-OEM device in the vehicle. For permanently installed LFAPs, an add-on guard that folds down with the pedal assembly when not in use by the driver or when being used by a nondisabled driver could be installed. It may be appropriate to specify a right-side pedal stop/guard be installed with all LFAPs and that all guards be capable of withstanding a defined minimum load with no distortion or movement that would affect the performance of the OEM accelerator.

The design height of the vertical shaft and the pedal size of the Drive-Master LFAP could allow the driver's toe to fall under the bottom edge of the pedal and against the vertical shaft while the heel becomes jammed into the floor covering. This could result in the accelerator being held in the open position with the driver unable to remove the foot from the accelerator in the normal toe lifting action. This may occur with drivers smaller than the 60th percentile male, depending on foot size and shoe style. This issue was also mentioned in Section 4.1.2.

Improper frequency of cleaning and maintenance of the removable LFAP could result in a buildup of debris such as snow, sand, mud and salt, particularly during the Canadian winter. If the removable portion is removed and then replaced without thoroughly cleaning the latching mechanism area, the removable portion may appear and feel as locked in place but may not be. This could lead to the removable portion

coming loose during driving, resulting in possible dangerous effects as described for loose fasteners. This subject is also discussed in Section 4.1.6.

Pedal placement may be one of the most important safety issues related to LFAPs. Manufacturers vary on how they address the issue of pedal placement, and in most cases leave the final decision to the installer. This places a high degree of responsibility on the installer to understand the mechanical and ergonomic issues related to the location of the pedals.

Drive-Master suggests the preferred rule of thumb is to place the left-side pedal at a distance and depth equivalent to the right-side OEM accelerator pedal. If this is not possible, it is recommended that extra care be taken to ensure that the location of the pedal does not allow the driver to press both brake and accelerator at the same time or that it does not allow the foot to become trapped between the brake and accelerator.

dSi suggests that the left-side pedal be located at a distance and depth equivalent to the right-side OEM accelerator pedal and that the adjustment for the vertical arm be as close to the OEM accelerator as allowed by the two positions available. If there is a foot-operated parking brake, the instructions advise placing the left-side pedal such that the space between the service brake, the LFAP and the parking brake is equal. The instructions do not address situations where these settings may not be possible or where the space between the left-side pedal and either or both of the two brake pedals may be wide enough to allow the foot to become trapped between either brake pedal and the LFAP.

Howell Ventures does not directly address pedal location other than to place the LFAP so as to allow easy operation of the vehicle.

MPD suggests the left-side pedal be located at a distance and depth from the brake equivalent to right-side OEM accelerator pedal. If there is a foot-operated parking brake, the instructions advise ensuring that the parking brake can be fully activated without interfering with the left-side pedal. The instructions do not provide an alternative if any of these directions are not possible, other than not to use the device in a vehicle where the distance between the brake pedal and the left-side pedal cannot be equal to the distance between the brake pedal and the OEM accelerator pedal.

The introduction section of the MPS manual states that there must be adequate clearance between the left-side pedal and the brake pedal to ensure that the left foot does not apply the brake and accelerator simultaneously. The operating instructions also caution to leave enough clearance between the left-side pedal and the brake pedal so that the left foot can move freely and not be able to press both the LFAP and brake pedal at the same time. The installation instructions recommend ensuring that the overall location of the device is compatible with the vehicle OEM accelerator, brake and other obstructions. They also request that the left-side pedal be located keeping in mind the driver's needs and the constraints of the vehicle.

Pedal placement is one of the weakest areas in the design and installation of LFAPs, and a search for information relating to the placement of automobile control pedals indicates that there is a general shortage of published standards, guidelines and information in this area. Most available information is researched/discussed in automotive ergonomics studies related to pedal errors and unintended accelerations.

The following is extracted from *Unintended Acceleration: Human Performance Considerations*, by Richard A. Schmidt:

> *"Pedal configurations.* Several analyses of the pedal configurations of existing vehicles have been made, in an attempt to correlate particular configurations with the rates of reported unintended acceleration.
>
> It is difficult to argue that certain kinds of pedal configuration are more or less prone to generate pedal misapplications and unintended acceleration.
>
> Others have suggested possibilities for a redesign of the pedal arrangements to minimize the likelihood of pedal errors, but each kind of modification would have other drawbacks and side-effects (see Office of Defects Investigation, 1989; Wierwille, in press). For example, separating the accelerator and brake pedal horizontally should reduce the likelihood of pressing the accelerator rather than the brake, but would produce increased movement time from the accelerator to the brake in 'panic-stop' situations, which is generally considered an unacceptable trade-off. Also, separating the pedals too far might allow some drivers to get their feet caught between and under the pedals under certain circumstances."

There is a need for better instructions to the installer by the manufacturer to ensure appropriate placement of the left-side pedal in a wide variety of vehicle situations. Installers report that most installations do not or cannot meet the specifications provided by the manufacturers. It is uncertain whether information required by manufacturers to provide these instructions is readily available.

It may be appropriate, as part of the effort to improve safety and installation quality, to conduct a comprehensive review of available literature to define the parameters appropriate for acceptable location of automobile foot pedal controls. This information could become reference data for manufacturers and installers of LFAPs.

The issue of pedal placement and clearance also raises the issue of proper vehicle selection. Although manufacturers and installers state that LFAPs can be installed in any vehicle with automatic transmission, it was discovered that in the trial installation of these devices as part of this project, of the four vehicles selected, one could not be fitted and another presented significant pedal spacing problems. Vehicle selection plays an important part in the safe operation of an LFAP.

It may therefore also be appropriate to conduct a comprehensive study of minimum three dimensional space requirements for LFAP installations or, alternatively, to produce a list of vehicles or classes of vehicles that can/cannot be adapted for LFAPs to be used by OTs and installers. Such a list would require continuous maintenance and updating which may be cost prohibitive.

4.2 Installation Summary

Various sources were used to identify installers in Canada, including a list of N.M.E.D.A. members and lists generated by rehabilitation centres, manufacturers and distributors.

4.2.1 Installer Profile and Qualifications

The installers contacted are located mainly in Ontario and western Quebec, and are involved in the installation of all types of adaptive aids, from fully modified vans to individual components. Typically, these companies have been in business for 10 to 20 years. Based on discussions with installers and reviews of the N.M.E.D.A. membership listing, it is estimated there are 40 to 45 companies in Canada who install LFAPs. Of this number, an estimated 20 percent are not members of any industry association such as N.M.E.D.A. or ADED.

A typical installer will have between one and three persons installing equipment into vehicles. These persons are typically technicians who are trained in hardware assembly but who have no specific formal training for the installation or use of adaptive aids. Ergonomics issues as well as the special needs and abilities of their customers are generally not known by new staff, most of whom are trained on the job by experienced staff. In the case of larger installer operations, LFAP manufacturers have trained the senior staff, who typically become trainers themselves. There is no certification or formal recognition of training. Eighty percent of the companies contacted are members of both N.M.E.D.A. and ADED. The remaining 20 percent either are not members, do not know if they are members, or are just now thinking of applying for membership.

The installation of LFAPs typically represents a very small percentage of an installer's revenue, ranging anywhere from 0 to 2 percent. The companies located in larger population centres such as Toronto and Montreal perform the largest number of LFAP installations, ranging between 30 and 70 per year. In smaller regions such as eastern Ontario, companies install 10 or fewer a year. A number of installers of adaptive aids contacted have never installed an LFAP, although they are willing and able. Specific sales data was difficult to obtain from installers and was provided as a wide range of possible sales by each supplier (e.g., 20 to 40 per year, etc.). Based on the information available, it is estimated that between 200 and 300 LFAPs are installed annually in

Canada. This data is not verified and somewhat unreliable. In order to obtain a more accurate estimate, a survey of manufacturer's distributors/dealers, similar to the one currently being conducted by Louisiana Tech University for the U.S. market, would need to be performed in Canada.

4.2.2 Installation Practices

Most of the installers interviewed (80 percent) require prescription by an OT prior to agreeing to install an LFAP. An additional group of installers (10 percent) will install LFAPs based on the recommendations of a certified motor vehicle driver instructor, without an OT's or physician's prescription. Both these groups recommended further driver training by third parties and none of the installers offered driver training. The remaining 10 percent of installers will install/sell an LFAP to an end user without any requirements for driver training or prescriptions from physicians or OTs.

Most of the installers interviewed keep one to six LFAPs in stock and purchase primarily from the manufacturer or, if necessary, from larger distributors/dealers or installers. Vehicle installations are normally scheduled by appointment, anywhere from same day to five days. Typically, an LFAP installation takes 3/4 of an hour to 1½ hours, including installation checkout and verification. This can extend to more than three hours for more complex installations, mostly as a result of vehicle configuration in the driver's space. Most installers suggest routine servicing every six to twelve months; however, they find that end users do not typically return for routine service/adjustments.

Typical LFAP installation costs range from CAN$125 to CAN$150 for the permanently installed type, CAN$355 to CAN$425 for the majority of the removable types, and approximately CAN$590 for the more expensive removable type. If the installation takes more than 1½ hours for a particularly complex vehicle, these costs will increase by about CAN$60 per hour. Most installers interviewed are paid directly by the end user; however, the installers feel that 50 percent or more of end users are reimbursed through vehicle rebate programs, health/workplace insurance and rehabilitation programs.

4.2.3 Vehicle Installations

The installers interviewed had experience installing Drive-Master, MPD, MPS and Howell Ventures LFAPs. No installers interviewed had installed the dSi FujiAuto. The LFAP model the installer uses is primarily determined by which manufacturer the installer represents as a dealer. The installers often carry a manufacturer's complete line of adaptive aids and thus promote that manufacturer's LFAP; however, they usually have an alternate, less expensive LFAP model from a different manufacturer to suggest, to satisfy the full range of their customers' budget tolerance. The installers

stated other specific reasons why they felt their products were superior, such as better design, easier installation, more adjustability and easier maintenance.

LFAPs are installed in a wide variety of vehicles, including compact cars, sport utility vehicles, trucks and vans. The main requirement is that the vehicle must be equipped with an automatic transmission. The principal market is intermediate and full-size cars, which, from the driver's perspective, are easier to access, have a larger and more accommodating driver's space, and which older drivers tend to prefer. From the installer's perspective, larger cars typically provide easier installation because the floors are less complex and the vehicles are better suited to the needs of the drivers. No modifications are made to their existing OEM safety features.

For the vast majority of vehicles, no modifications are required to install the LFAP. On vans, smaller cars and some sport models, the intrusion of the driver's side fender well and floor contours may inhibit or make the installation impossible. The shape of the vehicle panel structure in the pedal area may be such that there is insufficient room to space the pedals appropriately or to allow full movement of the left-side pedal. In some cases, the panel structure may be modified to provide greater clearances; however, this is restricted to minor dimensional changes. In some models of vehicles, the steering column may also impede movement of the foot from the left-side pedal to the brake. In some vehicles, such as the Chevrolet Astro van for example, the brake pedal is offset to the right of the driver's centreline and as such, is biased for right foot operation. This presents a difficulty in that drivers using the left-side pedal must move their left leg across the driver's position centreline to reach the brake, causing the left leg to be stressed and more susceptible to fatigue.

Potential problem areas related to LFAP installations in motor vehicles can be divided into three categories:

Vehicle issues

- wiring, brake lines and fuel lines in the area where the holes are drilled to attach the LFAP mounting plate;
- frame structure below the floor panel for floor- mounted LFAPs may not allow access for proper securing of fasteners;
- wheel well intrusions may not allow enough space for the left-side pedal placement or for full movement of the pedal when installed;
- wheel well intrusions or emergency brake mechanisms may not allow adequate space for the left-side pedal to fit between these items and the service brake;
- floor contours may not allow the mounting base plates to seat properly and may require excessive shimming;
- older vehicles can present installation problems such as rusting in the floor pan.

Installer issues

- installers using self-threading hardware, such as lag bolts, to fasten the device in place may drill holes that are too large and do not provide adequate thread holding strength;
- installers may position the pedal incorrectly, providing inadequate clearance between the left-side pedal and the brake or the emergency brake, especially if they do not take into account a full range of seasonal footwear;
- installers may not ensure there is full movement of the left-side pedal to allow actuation of the downshift mechanism necessary for engaging the passing gear;
- installers may not properly adjust the right-side actuator arm to allow the roller to run smoothly without jamming or rolling off the top or bottom of the OEM accelerator pedal;
- installers may not properly torque all the fasteners and adjusters on the device.

Maintenance issues

- drivers may not take their vehicles to the installer for routine maintenance such as cleaning and lubrication, fastener torque checks, and functional verification. Many fastening points are friction clamping mechanisms and can work loose over time. Lack of proper lubrication can prevent the pedal assembly from operating smoothly. Lack of lubrication can also prevent removal mechanisms from functioning;
- drivers may not keep the floor area around the device fee from debris such as sand, salt, mud and snow. This may cause the device to malfunction as an accelerator pedal or may prevent the removal/replacement or folding out of the way of the pedal assembly. A malfunctioning accelerator becomes a safety issue for the driver. Removal/replacement/folding problems can lead to a nondisabled driver operating the vehicle with the device still in place.

4.2.4 Installation Instructions

Because installers do not have their own installation instructions, they depend almost entirely on the installation instructions provided by the manufacturer. In some cases, the manufacturer has visited the installer's facilities and discussed the installation of the device with the installers. The installers interviewed found the manufacturer's installation instructions provided with each device to be adequate. The installers also noted that the installation instructions were followed as closely as possible, taking into consideration all the variations in vehicle configurations and pedal spacings, and that they used common sense along with these instructions to complete the installation.

A review of the installation instructions provided by the manufacturers showed that there is a wide variation in the information provided, from a single instruction sheet with no dimensional information to a 12-page instruction booklet including illustrations showing correct and incorrect location of components as well as notes referring the installer to the special needs of the customer and emphasizing the need for special driving training and maintenance schedules.

In addition to using the components provided with the pedal assembly (e.g., bolts, washers) the installer may find it necessary to add a levelling plate under the carpeting to remove extreme irregularities of the floor pan in the area of the mounting block/base of the LFAP. Once installed, the extension of the horizontal cross-axle assembly to the left of the left-side pedal must be shortened to accommodate the vehicle's contours and prevent it from protruding beyond the left-side pedal. This may restrict the transferability of the LFAP to another vehicle requiring a longer cross-axle assembly. Some installers indicated that, in order to fit the vehicle, the left-side pedal or pedal arm may need to be bent beyond the normal manufacturer's adjustment. This also applies to the right-side actuator arm of the LFAP to adapt it to the OEM accelerator pedal. Some installers modify the floor-mounted LFAP by fabricating their own bracketing to allow the LFAP to be mounted on the firewall or steering column instead of on the floor because they feel the action from a suspended LFAP is better matched to the action of the OEM accelerator pedal. This method of installation also allows the LFAP to be easily moved out of the way for nondisabled drivers by suspending it from a dash-mounted latch or velcro strap. The procedures described in this paragraph are not provided in the manufacturers' written installation instructions.

Regarding the issue of transferring an LFAP from one vehicle to another, installers reported that this was achievable in 90 percent of the cases. In the remaining 10 percent, previous modifications to the LFAP would not allow the device to be installed properly in the target vehicle. One manufacturer's installation instructions specifically stated that the base plate must not be transferred to another vehicle independent of the rest of the pedal assembly. The base plate and pedal assembly are a matched unit and the manufacturer will not warrant the transfer of the removable pedal assembly into another vehicle with a second base plate.

4.2.5 Installation Checkout

Installers indicated that they do not have written checkout procedures specific to their own company. They follow the procedures, if available, in the manufacturer's literature and usually verify the installation with a second technician, reviewing the work and checking functionality of the LFAP. Most installers also have a senior technician, who is familiar with the device, road-test the vehicle prior to delivery.

A review of the installation instructions provided by the manufacturers showed that there is a wide variation in the installation checkout procedures, ranging from a single

statement, "to check and make sure it runs smoothly", to complete post-installation instruction procedures detailing functional checks, road tests, and customer handover procedures, including verification that the LFAP has been adjusted for the driver's comfort and fit.

4.2.6 Customer Delivery and Post-delivery Services

Installers indicated they ensure the driver is comfortable with the installation and understands how to operate the device. Installers do not provide driver training but strongly recommend to each user that further practice and training be pursued (such as practise driving in vacant parking lots and on quiet roadways) prior to tackling busy traffic situations. Manuals provided by the manufacturers of LFAPs provide operator instructions for drivers ranging from none to multi-page guidelines including suggested training, parts manual, maintenance procedures and schedules, and warranty cards. Most installers stated that they passed the full Installation Instructions/Owner's Manual on to the customer for future reference.

Installers suggest to most users that they drive for a few days and then return to have any adjustments made for comfort. Installers interviewed indicated, however, once customers accept delivery, they do not usually return for further adjustment or service.

5 ERGONOMIC ASSESSMENT OF DEVICES

5.1 Ergonomics Analysis Methods

The scope of the human factors portion of the project is as follows:

- to analyse the activities of the LFAP user;
- to define the skills and capabilities required to operate an LFAP in a driving situation;
- to define the LFAP driver's learning process to ensure that these skills and capabilities can be optimally developed or enhanced;
- to identify specific difficulties in the use of an LFAP;
- to analyse the task of installing an LFAP;
- to define situations in which errors can be made that compromise the safety and efficiency of the LFAP; and
- to determine methods of preventing these errors, recovering from the errors, and/or mitigating the consequences.

The following tools were used by Blackwater's subcontractor, PHF Services Inc., to carry out the ergonomics portion of this evaluation:

- task and error analysis;
- questionnaires; and
- evaluation of existing standards and guidelines.

5.1.1 Task and Error Analysis of User Actions

A task analysis was completed to assess the actions required by LFAP users to operate a vehicle successfully and safely. The analysis consisted of breaking down the activity of driving using an LFAP into individual task steps, and then assessing each step for potential errors. The potential errors can be categorized as follows:

- errors of omission (not doing something that should be done)
- errors of commission (doing something wrong)
  - action carried out too soon
  - action carried out too late
  - action carried out too much (e.g., overbraking)
  - action carried out too little (e.g., underbraking)
  - right action on the wrong object (e.g., depressing the accelerator instead of the brake)
  - wrong action on the right object (e.g., indicating right instead of left).

The information requirements of the drivers were recorded to give the analyst insight into the skills, knowledge and capabilities necessary to complete the tasks. In addition, the consequences of potential errors were recorded. This information was used to help the analyst determine the significance of the skills, knowledge and capabilities (e.g., if the consequences are not safety related, they may not be considered as high a

priority as those that are).

The task and error analysis reveals aspects of the LFAP design that can be improved to reduce the likelihood of potential errors.

5.1.2 Definition of Skills and Capabilities

The task analysis data was used to determine the skills and capabilities required by a person to operate a vehicle using an LFAP. Specifically, the information that the driver needs to know offers information about the skills and capabilities of the driver. For example, the information requirement to know what is behind and on each side of the vehicle before making a manoeuvre indicates that the driver must have adequate vision as well as sufficient neck strength and mobility. Potential errors also yield information about the required skills and capabilities of the driver. The driver must possess the skills and capabilities to avoid such errors. For example, if the error described is failing to brake in a timely fashion, then the skill required by the driver is the ability to react within a short time frame.

5.1.3 Administration of Questionnaires

Questionnaires were developed for LFAP users, OTs who prescribe LFAPs, driving instructors who teach people to use LFAPs, and installers of LFAPs. The purpose of the questionnaires was to obtain views and opinions about a number of aspects relating to the use and installation of LFAPs.

Questionnaires were completed by seven OTs, three users and two instructors, either directly or by telephone interview. Occupational therapists were from clinics in the eastern Ontario region (i.e., Ottawa, Cornwall, Kingston, Perth and Toronto) as well as one clinic in Halifax, Nova Scotia. Each user who participated in the study was prescribed the pedal for different reasons (i.e., above the knee amputation as a result of cancer, loss of right side function as a result of a spinal cord injury, and loss of right side function as a result of a stroke).

5.1.4 Task and Error Analysis of LFAP Installation

A task and error analysis was conducted to assess the actions required by LFAP installers to successfully install and check out a vehicle. The analysis consisted of breaking down the installation process into individual task steps, and then assessing each step for potential errors. The potential errors can be categorized as follows:

- errors of omission (not doing something that should be done); and
- errors of commission (doing something wrong).

The information requirements of the installers were recorded to give the analyst insight into the skills, knowledge and capabilities necessary to complete the tasks. In addition, the consequences of potential errors were recorded. This information was used to help the analyst determine the significance of the skills, knowledge and capabilities (e.g., if the consequences are not safety related, they may not be considered as high a priority as those that are).

The task and error analysis reveals aspects of the LFAP installation that can be improved to reduce the likelihood of potential errors.

5.2 Results of User Task Analysis

The results of the user task analysis are contained in Table A1 in Appendix A. The main potential errors can be summarized as follows:

- under- and overacceleration;
- failure to operate accelerator;
- under- and overbraking;
- failure to operate the brake;
- under- and oversteering; and
- misjudging distances and size of obstacles.

The results of all errors fall into two categories: potential for a collision or causing obstruction (which, of course, may lead to a collision). All potential consequences have safety-related significance and therefore all potential causes must be addressed.

There are elements of the task analysis that relate to the task of driving in addition to those related to the use of the LFAP (e.g., moving around obstacles and judging the size of obstacles). These elements are still considered to be relevant, however, because the injury which lead to the incapacitation of the right foot/leg/side may have caused other physical and/or cognitive impairments. Furthermore, any reduced capabilities that affect any elements of driving may result in another type of modification to the vehicle being more suitable than the LFAP.

The potential causes of the errors must be explored to yield useful information about prevention. Under- and overacceleration may simply be due to the fact that the left foot is not as sensitive as the right. People are not as accustomed to operating an accelerator with the left foot, although there have been some cases documented where drivers have used their left leg to operate the brake and OEM accelerator. Practice may resolve this issue. Failing to accelerate could be the result of the driver missing the accelerator when trying locate and depress the pedal. This may have implications for the size and location of the pedal. However, it may be a cognitive issue – the driver may not be able to successfully send the message to the left foot to depress the pedal. The driver may also still be trying to use the right foot, which could result in pain or injury, and/or obstruction of the left foot operation.

Underacceleration or failing to depress the accelerator may, of course, be due to the driver's lack of strength to perform this action successfully. This must be detected as a cause at the beginning of the process. If sufficient strength cannot be exerted, then either the decision to use an LFAP should be delayed until the driver's strength has increased, or an alternative driving aid must be sought.

5.2.1 Definition of Skills and Capabilities

The skills and capabilities defined by the task analysis can be categorized as follows:

- physical abilities;
- cognitive abilities;
- behavioural attributes;
- generic skills; and
- driving skills.

Physical Abilities

The physical capabilities necessary for a person to be able to drive a vehicle using an LFAP are:

- vision that meets licensing requirements;
- upper extremity strength, range of motion, sensation and coordination (function) necessary to effectively operate the steering wheel and auxiliary controls;
- neck strength sufficient to hold head in a suitable position for prolonged periods of time and neck mobility sufficient to turn head to look over both shoulders as well as straight ahead;
- left foot strength, range of motion and coordination necessary to operate the LFAP and brake;
- proprioceptive and touch sensation in the left foot necessary to operate the LFAP and brake;
- sitting balance sufficient to maintain the upper body in an appropriate position; and
- ability to get in and out of the vehicle, and to load/unload a mobility device.

Cognitive Abilities

The cognitive skills necessary for a person to be able to drive a vehicle using an LFAP are:

- the ability to learn new skills;
- adequate long term memory to retain new skill;

- visual scanning skills and attention to visual details sufficient such that the driver is able to note other vehicles, pedestrians, bicycles, and traffic signs and signals;
- the ability to concentrate for extended periods of time;
- mental processing speed necessary to deal with moving stimuli;
- the ability to multitask;
- insight regarding abilities and the need to learn to use an LFAP; and
- suitable reaction time.

Behavioural Attributes

It is perhaps easier to discuss undesirable behavioural attributes of a driver rather than the desirable ones:

- overly aggressive while driving (short temper);
- demonstrating panic behaviour leading to irrational actions;
- overly passive while driving (driving slowly, inability to change lanes); and
- demonstrating impulsive or unpredictable actions.

Generic Skills

The generic skills necessary for a person to able to drive a vehicle using an LFAP are the ability to:

- judge distance;
- judge speed;
- learn and retain knowledge of signage and the rules of the road; and
- react appropriately to an ever-changing environment.

Driving Skills

The driving skills required to operate a vehicle using an LFAP are defined as the ability to:

- adjust mirrors, fasten a seat belt, start the vehicle, operate the gear selector;
- pull away from the curb and merge with traffic;
- move with the flow of traffic;
- maintain a constant speed and adjust speed when necessary;
- move around obstacles;
- adopt a suitable position on the road and in the lane;
- stop suddenly when required;
- slow at the proper time;
- stop at the correct position on the road;
- maintain adequate space cushion behind and beside other vehicles;
- observe traffic/pedestrians/others;

- anticipate and respond to potential hazards;
- demonstrate good judgment and decision making;
- adapt to weather changes;
- complete safe lane changes;
- perform safe right and left turns;
- drive in reverse; and
- perform parking manouevres.

5.3 Questionnaire Results

5.3.1 Consultations with Occupational Therapists

LFAP assessment programs vary from clinic to clinic. Some OTs use very well documented procedures, while others deal with clients on an individual basis. Some clinics have access to driving simulators (e.g., Doron Simulator), while most do not. This has led to the use of a broad range of assessment protocols, although the difficulties experienced by clients are similar.

All of the clinics that participated in this study evaluate both the physical and cognitive abilities of the client, but there are differences in the tests they employ. The most common cognitive evaluation process combines the Cognitive Behaviour Driving Inventory (CBDI) and the Mini-Mental Status. This combination is necessary, because the CBDI does not evaluate memory and the Mini-Mental Status does. Other clinics have either developed their own tests or use a variety of others.

The majority of cognitive tests, with the exception of the CBDI, are general tests that are used in other disciplines for similar processes (e.g., psychiatry or psychology). Care must therefore be taken that the OT does not repeat tests already administered to the client by a psychiatrist or psychologist, thus compromising the validity of the test, because the client, who will have seen the same test twice, could have 'learned' responses.

There is no standardized test of physical capabilities; however, each OT assesses client capabilities in a similar fashion. A series of tests is conducted to evaluate the range of motion, strength sensation and coordination of the upper and lower extremities. Based on these evaluations, the OT then makes a decision as to whether the client can use the right lower extremity to operate the OEM accelerator pedal and brake, if an LFAP or alternate adaptive driving aid is required, or if the client is not permitted to drive. OTs who have access to a simulator agree that its use in the training process significantly reduces the amount of in-car training necessary for the driver. It allows drivers to become accustomed to using of their left foot in a consequence-free environment, which can be a very effective way of learning. Drivers can then practise in traffic when the LFAP is no longer totally new to them.

By far, the most common difficulty associated with LFAPs, as seen by OTs, is ensuring that drivers use their left foot as the dominant foot in a driving situation. Typically the right foot is dominant and the left foot is passive or plays a minor role (i.e., in standard transmissions). Using the left foot is made more difficult by the trained knowledge learned response that the right-side pedal is normally the OEM accelerator and the left-side pedal is normally the brake. This is particularly evident when drivers are forced to make an emergency stop, at which time they may become confused and try to use their right leg, or depress the left-side pedal thinking that it is the brake.

This situation occurred in a recently documented incident in the province of Nova Scotia, where a driver was involved in an accident in a parking lot resulting in damage to three vehicles. No personal injury was sustained.

Clients complete an in-house evaluation with an OT as well as an on-road evaluation with an OT and a driving instructor who has experience in driving rehabilitation. Once it has been determined that the client requires an LFAP, based on physical, cognitive and behavioural abilities, the client then completes the necessary training with the driving instructor. When it is decided that the client can safely operate a vehicle with an LFAP, then most OTs provide the client with a list of installers or one in particular that they have worked with and trust. The OT may prescribe a specific model or design preference (e.g., one with a stop/guard over the OEM pedal).

5.3.2 Consultations with Users

Three users were contacted with regard to their experiences with LFAPs. Although their reasons for requiring an LFAP were different (paralysis, stroke, amputation), their experiences were very similar. Each user was concerned when beginning training but became comfortable using the LFAP following five to eight hours of instruction.

Medical background as well as driving experience appeared to dictate how quickly the users became comfortable. The driver suffering from paralysis had experience driving a standard transmission vehicle and was 27 years of age with no cognitive impairments. This user became comfortable after only five hours of instruction. The driver who suffered from a stroke at age 33 was still taking instruction at the time of the interview. This user had both physical and cognitive impairments and expected to require seven to eight hours of instruction. The third driver, who became an amputee at the age of 76 and had no cognitive impairments, underwent five hours of instruction and felt comfortable.

Like the OTs, the users found that the most difficult aspect of learning to use the LFAP was making the automatic association between the accelerator being located to the left of the brake and the left foot as the dominant foot. All three users strongly recommended that users obtain training before purchasing an LFAP and having it installed in their vehicle.

5.3.3 Consultations with Driving Instructors

Two instructors were contacted and asked about their experiences with LFAPs. Neither instructor had received any special training for the instruction of persons in the use of adaptive driving aids. Their experience came from discussions with OTs and their training as driving instructors.

Both instructors stated that a minimum of three hours training in a car is required and that many people require more. They have each worked with a variety of clients, including stroke patients and amputees. Neither instructor reported having any users who failed to become proficient using an LFAP. They equated the instructional process with instructing a new driver and approached it accordingly. Both noted that drivers require varying amounts of time to become proficient with an LFAP. They also said that the factors affecting the speed with which a user becomes proficient are age and presence or absence of cognitive impairments.

Like both the users and OTs, the instructors stated that the most common problem associated with learning to use an LFAP was making the left foot the dominant foot and intuitively understanding that the accelerator was now to the left of the brake.

One of the instructors had no reservations about consenting to instruct users who were not referred by an OT. The other instructor had, in the past, instructed users without a referral; however, over the last few years that instructor realized that the interaction between the OT and the instructor is important because each looks for different things, which helps to give a better overall assessment of the user's capabilities. For this reason, this instructor no longer instructs users that have not been referred by an OT.

5.4 Results of Installer Task Analysis

A task and error analysis was undertaken to evaluate the installation process and to identify any sources of potential error during that process. The results of the installer task and error analysis are contained in Table A2 in Appendix A. The main potential errors can be summarized as follows:

- fixing the mounting bracket or assembly in the incorrect location;
- failing to properly adjust the roller position on the OEM pedal; and
- failing to properly adjust the location of the left-side pedal with respect to the brake pedal.

These errors will result in the user not being able to use the LFAP properly and potentially being involved in a collision or causing an obstruction that may result in a collision. All potential consequences have safety-related significance and therefore all potential causes must be addressed.

Incorrectly locating the mounting bracket or assembly could result in the LFAP not functioning properly, and may lead directly to the incorrect adjustment of the LFAP's components. All of the LFAPs in the task analysis were equipped with a roller on the actuator arm. If this roller is positioned incorrectly on the OEM pedal, the roller could fall off the top or bottom of the OEM pedal, or lock the OEM pedal in a partial or full activation position. Finally, if the LFAP is not positioned properly with respect to the brake pedal, there is the potential for applying both pedals concurrently.

The source of errors associated with the LFAP installation process is mainly the result of variations in vehicles that lead to the need to adapt the LFAP to the specific vehicle. These variations may require installers to alter the installation procedures as outlined by the manufacturer, or discard them entirely. It is therefore important that installers be knowledgeable about the LFAP they are installing, the vehicle into which it is being installed, and the special needs of the client.

5.5 Summary of Ergonomics/Human Factors Considerations

To maximize the safety and efficiency of the LFAP from a user's perspective, each stage of the process – from being prescribed an LFAP and learning to use it, to purchasing the LFAP and having it installed, to driving a vehicle equipped with an LFAP – must be addressed.

5.5.1 The Prescription Process

The process of deciding whether it is appropriate for a person with a disability to drive using a LFAP must include an assessment of whether that person has the appropriate cognitive capabilities, physical capabilities and behavioural attributes.

5.5.2 The Instruction Process

The instruction process must address both generic skills and specific driving skills, and ensure that an appropriate skill level is reached.

5.5.3 Purchasing the LFAP

The safest, most efficient design should be selected, based on an evaluation of the LFAPs available on the Canadian market, to ensure that the LFAP possesses the appropriate design features, and that it is possible to install the LFAP into the client's vehicle safely and effectively.

5.5.4 The Installation Process

The installation process must be supported by thorough and well-designed installation procedures, appropriate training of the installers, and quality assurance procedures.

5.5.5 Use of the LFAP in the User's Own Vehicle

The process of learning to use the LFAP should be continued in the driver's own vehicle to ensure that drivers become comfortable with any differences between their vehicle and that of the driving instructor, before being permitted to drive their vehicle unsupervised.

6 DISCUSSION

6.1 Engineering and Ergonomic Assessment Results

The results of the engineering and ergonomic assessments illustrate the degree to which equipment failure, poor installation and ergonomic considerations, and/or driver error are responsible for accidents/incidents involving LFAPs. The results are summarized in the following table:

Factor	Contribution to Accidents/Incidents	Methods to Minimize Problems
LFAP Prescription	Low	* Appropriate OT assessment * Standard testing * Education of OTs, drivers and installers
Driving Instruction	Low	* Work with OT * Education of instructors and drivers
LFAP Design	Medium	* Establishment of design specifications (e.g., torque, service loads and service life) * Provision of accurate and complete Installation Instructions * Specification of maintenance schedules * Establishment of pedal placement guidelines
LFAP Manufacture	Low	* Follow manufacturing best practices
Vehicle Selection	Medium	* Assessment of available pedal space * Assessment of driver suitability for selected vehicle * Education of drivers, OTs and instructors
LFAP Installation	Medium/High	* Provision of accurate and complete installation instructions * Education and training of installers

LFAP Use by Driver	High	* Assessment of driver * Training of drivers and installers * Licensing of driver * Assessment of available pedal space * Provision of right-side pedal stop/guard * Specification of maintenance schedules
LFAP Use by Nondisabled Drivers	High	* Provision of right-side pedal stop/guard * Labelling * Education of nondisabled drivers

This table lists the factors of concern, the risk each factor poses in use of the LFAP, and the higher priority actions or methods that will improve performance and safety. For example, the prescription process is generally a low contributor to accidents because OTs and driver rehabilitation centres perform very well. Methods to improve the process further include ensuring that the driver has appropriate OT assessment based on the required tasks as well as the physical and mental abilities of the driver. A standard, consistent testing procedure across the country would improve the reliability of evaluations. Another important factor in the prescription process is education of OTs and others working in the field so that they fully understand the implications and consequences that the installation and use of an LFAP in a vehicle can have for both disabled and nondisabled drivers. On the other hand, assessment of LFAP use by the driver currently may not be carried out at all, resulting in a high risk of accident. It is thus important to ensure that the requirements to allow installation of and driving with an LFAP clearly dictate a complete and strict assessment program, driver training program and licensing process. Driver error is a major cause of incidents and any actions that remove or reduce the possibility of driver error will significantly reduce risk in the use of LFAPs.

6.2 The Need for a Standard

Although manufacturers and installers are generally manufacturing and installing quality products, a standard would provide minimum levels of safety and quality to be met by every installed product. A standard would also provide the advantage of establishing a minimum set of known requirements for the driver and other interested or involved third parties. A standard should not deter the development of innovative products or product adaptations required by specific individuals. A standard should benefit all parties involved including LFAP users, the industry and regulatory agencies.

A standard would assure third parties involved with an LFAP-equipped vehicle that the manufacturer and installer have followed a recognized standard and that the final product meets a minimum set of safety, functionality and quality requirements.

In addition to benefiting people engaged in designing, manufacturing and installing LFAPs, having installed LFAPs meet minimum requirements would benefit road safety administration authorities, driving rehabilitation specialists, driving instructors, OTs and other health professionals engaged in the rehabilitation of people with physical disabilities.

Minimum requirements would also benefit the industry by facilitating vehicle servicing and maintenance. Maintenance documentation would meet specific criteria and thereby reduce the chance of a failed system due to improper maintenance procedures. These and other benefits have the potential to reduce accident, liability and insurance risks to the driver, the manufacturer, the installer and the general public.

Although the specification and regulation of driver training does fall under provincial jurisdiction, a developed standard should reference the necessity for thorough driver training after assessment and prescription. Driver training not only instructs an individual in the safe control of the vehicle in various hazardous situations, but also educates the driver on proper LFAP operation and necessary maintenance requirements.

6.3 Areas for Consideration in the Development of an LFAP Safety Standard

Standards and guidelines can be developed that are either prescriptive or non-prescriptive. A non-prescriptive guideline, for example, would be that the driving instructor must address the skill of parking the car. A prescriptive guideline would be that the driver must successfully park the car no more than 130 millimetres parallel to the curb, on six occasions. To meet the needs of the industry and other stakeholders, a prescriptive standard may need to be developed, with a non-prescriptive supplementary information section to provide additional advice and direction on product design, manufacture and installation, and on other topics such as driver training, installer training, driver assessment processes and the safe use of the product. This supplementary section would present valuable information that is not a mandatory part of the standard. The development of prescriptive portion of the standard or guideline would require a significant amount of additional research to base the requirements upon sound rationale.

One of the first steps in the process of standards development is to determine what, if any, standards or guidelines are needed to govern the prescription, design, installation and use of LFAPs.

LFAP Prescription Guidelines

It is outside the scope of this study to examine the decision-making processes leading up to the recommendation by an OT for the use of an LFAP. However, in the examination of issues affecting successful LFAP use, it is not possible to bypass this process completely.

The ergonomics assessment results indicate that certain behavioural attributes, physical capabilities and cognitive capabilities must be possessed by the driver before being prescribed an LFAP. The process used by OTs should therefore demonstrate that they address these areas.

A list of tests or recommended methods, approved as part of the evaluation procedure to assess each of these parameters, might be developed (e.g., CBDI, Mini-Mental Status, etc.) as well as standardized procedures and scoring for reaction time tests.

Driving Rehabilitation Centres performing evaluations of potential LFAP users might need to be certified or registered for compliance to a standard LFAP testing protocol.

The required use of driving simulators may be beneficial in ensuring that potential users become accustomed to using the LFAP in a consequence-free environment and learn to behave as if the left leg is dominant, prior to being exposed to traffic situations.

A prescription might be mandated before a driver can use an LFAP. Currently, anyone may decide to install and use an LFAP.

OTs should become familiar with all the aspects and consequences related to the installation and use of an LFAP in a vehicle.

Driving Instruction Guidelines

Guidelines should require some specific training and/or level of experience in instructing clients to use an LFAP.

Instructors should be required to demonstrate how they assess generic driving skills as well as how they address and test drivers' performance of driving tasks.

Instructors should be required to consult with OTs to review the driver's file and recommend an appropriate course of action to ensure successful rehabilitation.

A registry of driving instructors qualified to teach LFAP candidates may be maintained. There should be a standard minimum required time of instruction by a driving instructor

prior to the driver attempting the driving exam. If the driver does not pass the exam, further instruction time should be specified according to the nature of the exam failure.

A certificate from an OT and a driving instructor should be required prior to drivers taking their driving exam with the licensing authority.

Driving instructors should become familiar with all the aspects and consequences related to the installation and use of an LFAP in a vehicle.

LFAP Design Guidelines

Design is where safety and functionality are built into an LFAP. A standard would provide minimum design requirements for manufacturers to ensure products are designed and manufactured to an acceptable level of safety and functionality.

A specification for the minimum force required to be applied to the left-side pedal without causing a change in the relative position of the left-side pedal arm or the OEM pedal actuator arm would eliminate the problem of insufficient friction force clamping on the cross-axle assembly, for example. A standard would effectively specify a performance requirement for the friction clamp and eliminate the slipping of the clamp, which could cause a safety problem.

Pedal stops/guards over the OEM accelerator pedal should be required on all LFAP installations to reduce the accidental or learned-response application of the OEM pedal, particularly in times of stress.

All the performance requirements necessary for the safe and functional operation of an LFAP could be defined in a standard. A number of these items are noted in Section 4.1. Some examples include fastener torques, pedal placement, pedal stop/guard load requirements, fastener selection, hole size specification, labelling, maintenance and service life issues.

Installation instructions are the weak link in the design output. As suggested in Section 4.1.9, it may be appropriate to specify a detailed table of contents and general format for an installation manual to help manufacturers, installers and drivers to fully understand, correctly install and use LFAPs.

A process of combining could be used for installation and operating instructions as well as other data deemed necessary to fully educate all stakeholders. The resulting best practices table of contents and format could then be used as a guide by each manufacturer to produce documentation customized to its specific product.

LFAP Manufacturing Guidelines

Manufacturing is generally not a problem related to LFAPs. A recommendation in a standard that industry best practices be used for all processes involved in the manufacture of LFAPs and that quality records be maintained should be included.

Vehicle Selection Guidelines

As individuals, each of us prefers to drive a vehicle that reflects our personality and needs. Many vehicles available on the market that appeal to drivers do not have adequate space for correct and safe installation of an LFAP. Pedal placement and adequate clearances play an important part in the safe operation of an LFAP. It may be necessary to determine and specify a minimum spacial arrangement required to install an LFAP correctly. OTs, installers and vehicle owners/drivers should be given a guideline for vehicle selection.

Improper vehicle selection encourages the incorrect installation of LFAPs.

LFAP Installation Guidelines

This is the critical point at which the product becomes integrated with the vehicle.

Installers should be required to request that their clients present an OT prescription prior to performing the installation of an LFAP to ensure the correct adaptive aid is installed.

Manufacturers should be required to provide documented installation information to the installer and the end user. A standard could define the documents and specify content and format of presentation.

A standard could also require installation checklists and record keeping requirements related to the installation and other issues such as post-inspection actions, maintenance and warranty programs.

A standard could furthermore specify the training and certification requirements of installer organizations and employees.

A registry of qualified installers, based on criteria defined in the standard/guideline, could be maintained. Increased controls on installers, possibly in the form of licensing or a registry of accredited locations, may provide the required assurances. A random inspection of installers could be a condition of licensing.

Installers should become familiar with all the aspects and consequences related to the installation and use of an LFAP in a vehicle. As stated in Section 4.1.7, it may be appropriate to have a standard training course that ensures the installer is exposed to subjects such as: reading and interpreting installation instructions; the importance of fastener torque and hole sizes related to fasteners; understanding LFAP operation; appreciating the effects of incorrect component adjustment; general issues related to vehicle modifications; potential problem areas with respect to the function of the LFAP in different vehicles; implications concerning the modification of the manufacturer's device or its components; and an introduction to LFAP user needs and issues.

LFAP User Guidelines

Human error is the greatest factor affecting the safe operation of LFAPs and is a major cause of incidents. Any actions that remove or reduce the possibility of driver error will significantly reduce risk in the use of LFAPs. Improving pedal movement space, the relative location of pedals, and driver familiarity with the pedals will be a major step toward improving the safety of LFAP use.

Before being prescribed an LFAP, the driver must possess certain behavioural attributes, physical capabilities and cognitive capabilities. The process used to assess drivers should therefore demonstrate that these areas have been fully addressed. Drivers should be required to consult with OTs to review their file and the recommended course of action to ensure successful rehabilitation.

Driving simulators may be beneficial in ensuring that potential users become accustomed to using an LFAP in a consequence-free environment, and learn to behave as if the left leg is dominant, prior to being exposed to traffic situations.

A prescription should be mandatory before drivers can use an LFAP. Currently, anyone may decide to install and use an LFAP.

Specific training and experience in the use an LFAP, as well as a minimum time of instruction by a qualified driving instructor prior to the driver attempting the driving exam, should be required.

Drivers should require a certificate from an OT and a driving instructor prior to taking a driving exam with the licensing authority.

A detailed maintenance plan should be followed by LFAP users to reduce the potential for improper operation due to a lack of adjustment or lubrication, or as a result of the accumulation of salt, sand, ice and debris jamming the LFAP or preventing removable components from being reinstalled properly.

Drivers should become familiar with all the aspects and consequences related to the installation and use of an LFAP in a vehicle.

Nondisabled Driver Guidelines

A significant percentage of LFAP-related incidents is the result of persons other than the driver using the vehicle. Accidents occur when nondisabled drivers forget that the left-side pedal is still in place, operate the vehicle not realizing or ignoring the fact that the LFAP is installed, or use the LFAP without adequate training.

Pedal stops/guards over the OEM accelerator pedal should be required so that the nondisabled driver is aware on or before starting the vehicle that it has been modified, and can take steps to deactivate the LFAP.

As stated in Section 4.1.8, it may be appropriate to specify a decal be attached to the dashboard or other area to warn other drivers, particularly those not routinely familiar with the driver and the vehicle (e.g., mechanics, casual drivers of the vehicle, parking attendants, towing operators and others) that the vehicle has been modified for special needs.

Nondisabled drivers who routinely drive, or interact with the driver of, a vehicle modified for use of an LFAP, should become familiar with all the aspects and consequences related to the installation and use of an LFAP in a vehicle.

6.4 Development of a Canadian Standard

The development of a Canadian standard specifying performance requirements for LFAPs can be accomplished in a number of ways. The standard could be mandated as a regulatory standard that is entirely the product of the government. Alternatively, the standard could be a consensus standard developed and maintained through an organization such as the Canadian Standards Association (CSA); or developed as an SAE Recommended Practice and administered by an industry association such as N.M.E.D.A.

A future Canadian standard should include any existing applicable standards and recommended practices.

6.4.1 Implementation Options

There are several advantages and disadvantages associated with the implementation of a Canadian standard developed using the aforementioned approaches:

- An LFAP Recommended Practices document, developed and released by SAE, could be directly adopted by Transport Canada for incorporation into the Motor Vehicle Safety Act (MVSA). Incorporation into the MVSA is a lengthy process in which it can take several years to fully review and legislate the recommended practices. This method may also preclude the involvement of the industry and third-party interest groups. The advantage is that a federal standard with the associated enforcement mechanisms would be in place. All LFAP installations could be regulated and inspected for conformance.

- An SAE-developed LFAP Recommended Practices document could be used by the CSA to create an industry consensus CSA standard. Although quicker, it is a high-cost process and still involves lengthy industry reviews before the CSA standard is published. This approach involves industry and third-party interest groups in the development of the standard and incorporates related Canadian specifications and standards by reference.

  The CSA typically includes supplementary information in its standards to provide information not only on the design, manufacture and installation of products, but also on the application and safe use of the product. The advisory section of CSA standards typically presents valuable information that is not a mandatory part of the standard and may include:
  - methods to assess user abilities;
  - licensing requirements;
  - vehicle selection guidelines;
  - documentation format;
  - ergonomic considerations; and
  - advisory notes.

  This information may be provided as appendices to the standard or in the form of advisory circulars and may be an optimal location for driver assessment and training information.

  Options for this scenario are that the CSA standard could be adopted by the Government of Canada and referenced in the MVSA, or the standard could be incorporated into provincial regulations. Provincial adoption of portions of the standard rather than the entire standard can lead to variations in LFAP standards across the country.

- An SAE-developed LFAP Recommended Practices document could be adopted by an industry association such as N.M.E.D.A. This is the quickest, most cost-efficient method of establishing an industry standard. The industry can phase in the standard with direct industry input and education programs. The adopted document could be amended to include supplementary information, much as CSA standards do, to provide information not only on

the design, manufacture and installation of products, but also on the application and safe use of the product. The supplementary section would present valuable information that is not a mandatory part of the standard.

SAE has indicated that SAE standards related to adaptive aids such as LFAPs should, because they relate so much to driver issues, contain information on a broad range of factors such as:

- methods to assess user abilities;
- licensing requirements;
- vehicle selection;
- documentation format;
- ergonomic considerations; and
- advisory notes,

rather than just the normal technical specifications found in current SAE standards.

In this scenario, the standard would not be legislated and its use would be enforced by the industry association, thus affecting only its membership. Non-members would not be required to conform to this standard. Having only a portion of the manufacturers/installers working to the standard allows the potential for other manufacturers/installers to provide inferior product at similar or lower costs.

There are other methods of implementing a standard, but the three options described above are the most likely. Recommended practices would need to be developed and released by SAE prior to initiating any of these approaches. Therefore, some form of assistance to the LFAP Sub-committee of the SAE Adaptive Devices Committee would directly benefit the development and release of such documents.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

- The Canadian market for LFAPs is small (estimated between 200 and 300 per year) and the price is low in comparison with other automotive adaptive devices. LFAPs represent a minor segment of the product offerings and the revenue stream of manufacturers and installers.

- Accident/incident statistics and reports available do not reveal a high or unusual occurrence of incidents involving LFAPs.

- Existing documentation (industry association recommendations, best practices, guidelines) is minimal and general in nature.

- There is a lack of consolidated procedures of any kind for the design, manufacture, installation, maintenance, installer training and driver training related to LFAPs in Canada and the U.S.

- There is a lack of a defined or documented LFAP prescription process that identifies the LFAP as a suitable adaptive aid for a driver.

- Technical evaluation and trial installations of selected devices revealed various technical deficiencies in LFAP design. The technical deficiencies varied from device to device.

- Trial installations revealed that some vehicles, because of vehicle floor pan geometry, driver's seat location relative to foot controls, or general spacial constraints, are not suitable for the installation of an LFAP.

- The manufacturers' installation instructions and owner's manuals revealed various deficiencies in instructions. The deficiencies in the instructions varied from device to device.

- Based on an engineering and ergonomic review of design, manufacture, installation, driver training and driver assessment, a need exists in the industry for documentation to provide standardization, whether in the form of best practices, guidelines, industry standards or legislated standards.

- Based on a human factors review of installations, driver training and driver assessment, a need exists in the industry for documentation to provide standardization, whether it be in the form of best practices, guidelines, industry standards or legislated standards. There is a lack of evidence that all processes – from prescription to driving with an LFAP – are adequately supported to ensure safe operation.

- CSA has not seen, within the industry in Canada, a compelling reason or the financial support for the development of a CSA standard strictly related to LFAPs.

- Producing a Canadian legislated standard by government independent of other organizations, considering the small market and the low number of incident reports, is not likely a realistic, cost-effective option.

7.2 Recommendations

- Assistance provided to the SAE Adaptive Devices Committee sub-committee on Left Foot Accelerator Pedals would expedite the release of recommended practices and procedures for LFAPs and therefore expedite any of the options chosen for adopting the recommended practices as a Canadian standard. This support would be a cost-effective method to move toward a Canadian standard for LFAPs.

- The most efficient method of implementing a standard in Canada for LFAPs would be the direct adoption of released SAE documents by recognized industry associations such as N.M.E.D.A. and ADED. Adopting the SAE documents would reduce development time and costs. Use of a document developed by a recognized organization such as SAE would increase industry and third-party acceptance of the standard.

- The disadvantage of an industry standard is that it would only apply to industry association members and may not be voluntarily adopted by manufacturers and installers outside the industry association. For example, N.M.E.D.A. members must comply with N.M.E.D.A. guidelines to qualify for the association's quality control program. Encouraging N.M.E.D.A. membership would aid in establishing the broad use of an industry standard adopted by N.M.E.D.A. Associations such as ADED could assist in establishing the guideline by recommending that clients go only to N.M.E.D.A. member installers.

- Future work should focus on providing resources to assist the SAE LFAP Sub-committee in the development of a standard for the prescription, design, manufacture, installation and use of LFAPs that would include driver issues and contain advisory appendices on a broad range of factors such as:
  - methods to assess user abilities;
  - licensing requirements;
  - vehicle selection;
  - documentation format;
  - ergonomic considerations; and
  - advisory notes.

This support can be:

- Technical assistance by supplying members to the Sub-committee and providing resource funding to those members;

- A detailed survey of the mobility equipment dealers in Canada to fully quantify market sales and their demographic distribution, particularly as they apply to LFAPs. The Louisiana Tech University survey template used in a similar study of U.S. mobility equipment dealers could be used as a model;

- A study to determine the minimal spacial requirements in vehicles to allow for correct and safe pedal placement and configurations. This data could then be related to acceptable vehicles for currently available LFAPs and could be used by designers to define the limits of new and existing LFAP installation. Reference measuring points as defined in SAE J1100 (Figure 30 — Pedal Position Measurements - Automatic Transmission) could be used as a starting point;

- A study on the standardization of assessment and driver training methods used in Canada by OTs and Driver Rehabilitation Centres, possibly in conjunction with associations such as ADED; and

- Development of a pro forma table of contents and format for installation and operator's manuals that would indicate the information deemed necessary to properly install and operate an LFAP.

Participation by TDC/Transport Canada on the SAE LFAP Sub-committee should be provisional on the inclusion of advisory appendices in the SAE technically oriented recommended guideline.

APPENDIX A

USER AND INSTALLER TASK ANALYSES

TABLE A1 – APPENDIX A
TASK AND ERROR ANALYSIS FOR USE OF LFAP

Task Step	Information Requirements	Potential Errors	Consequences
Perform pre-driving checks: - mirrors and seat belts properly adjusted - handbrake on - vehicle in park or neutral.	Does the driver have clear vision behind and to the right and left side of the vehicle? Does the driver have tactile and visual feedback that the seat belts are secured?	Mirrors not positioned correctly. Seat belts not done up.	Driver is not able to use mirrors effectively. Driver is not restrained in seat.
If LFAP is removable, secure the pedal to the bracket on the floor.	What is the correct orientation of the LFAP assembly? Is there an indicator that the assembly is secured?	Pedals not secured properly.	Assembly could malfunction or become disengaged while driving.
Ensure components are in the correct location.	What is the correct location of the LFAP actuator roller on the OEM accelerator pedal? What is the correct location of the LFAP left-side pedal with respect to the vehicle brake pedal?	Components could be misaligned or in the incorrect location.	LFAP pedal may not function correctly. LFAP pedal may be too close to the vehicle brake pedal, causing the driver to apply both pedals simultaneously or mistake the left-side pedal for the brake pedal.
Start car.	Is the car already started?	Key turned too long. Key not turned long enough. Key turned when engine already started.	Vehicle is damaged. Driver is unable to start car.

Operate LFAP.	What is the target speed? Is there anything in the surrounding area that needs to be considered?	Overacceleration. Underacceleration. Failure to notice obstacles in the surrounding area. Brake depressed concurrently or solely. Attempt to use the OEM pedal.	Collision. Obstruction. Driver does not have the physical ability to control the OEM pedal.
Move with the flow of the traffic.	Does the driver have a perception of the vehicle speed and the location of other traffic?	As above.	Collision. Obstruction.
Move around obstacles.	Does the driver correctly judge the size and location of obstacles? Does the driver have the ability to judge the time available and required to move around the obstacle? Does the driver correctly judge how much room to leave between the car and the obstacle?	Failure to move out far enough. Moving out too far. Pulling in too soon. Pulling in too late.	Collision. Obstruction. Collision. Obstruction.

Operate brake.	Does the driver correctly judge the required level of braking? Does the driver take into consideration other vehicles and things in the surrounding area that may be affected by braking?	Overbraking. Underbraking. Foot transferred too quickly from the LFAP pedal. Failure to consider consequences of action on other vehicles and pedestrians in the immediate area.	Collision. Obstruction. LFAP assembly may move out of the proper position. Force other vehicles and pedestrians in the immediate area to take evasive action.
Operate turn-signal switch.	Does the driver signal the turn? Does the driver signal the correct turn direction?	Failure to initiate. Incorrect signal.	Collision. Obstruction.
Operate headlights and/or windshield wipers.	Does the driver recognize the need to turn on headlights and/or windshield wipers?	Failure to activate.	Lack of visibility may lead to collisions or obstructions.
Control speed.	Is the driver able to control the vehicle speed? Is the driver aware of the speed of other vehicles? Is the driver aware of the speed limit? Does the driver observe the speed limit?	Overacceleration. Underacceleration. Failure to maintain a consistent and appropriate speed.	Collision. Obstruction.

Adopt suitable position in lane.	Can the driver control the vehicle within the extremities of the lane?	"Floating" in the lane. Inability to maintain the vehicle within the lane.	Collision. Obstruction.
Change lanes.	Does the driver correctly judge the available space in the target lane?	Failing to determine if the target lane is clear. Over/understeering.	Collision. Obstruction.
Leave adequate space between vehicles.	How much space does the driver leave between vehicles?	Following too closely.	Collision.
Signal at the appropriate time.	When does the driver initiate the turn signal?	Initiating the signal too soon. Initiating the signal too late.	Other drivers are inadequately warned. Other drivers are confused.
Control steering around corners.	Does the driver steer around the corner correctly?	Over/understeering.	Collision.
Control speed during turns.	Does the driver negotiate the turn at a correct speed?	Driving too fast/slow.	Collision.
Turn into correct lane.	Does the driver turn into the correct lane?	Turning into incorrect lane.	Collision.
Observe traffic/pedestrians/others.	Does the driver notice obstructions in the roadway? How does the driver respond to the obstruction?	Failing to see an obstruction. Responding incorrectly to the obstruction.	Collision.

Obey signs and signals.	Does the driver understand and obey the sign or signal?	Incorrectly interpreting the sign or signal. Failing to recognize a sign or signal.	Collision.
Slow down in a timely fashion.	Does the driver understand why the vehicle should be slowed down?	Failing to recognize the need to slow down. Failing to slow down fast enough. Over-reaction and braking too hard.	Collision. Obstruction.
Stop in the correct position.	Does the driver understand where the vehicle should be stopped?	Failing to stop. Over/undershooting the target stop position.	Collision. Obstruction.

How do the following models of LFAPs address the potential errors associated with their use?

1. dSi, Fujicon, Model LA-2
2. MPD, Model 3545
3. Howell Ventures, Sure Foot
4. MPS, Left Foot Accelerator
5. Drive–Master, Model GS-150

1. dSi, Fujicon, Model LA-2

Installation in Vehicle

- the assembly is designed as a quick release for removal from the vehicle to allow nondisabled drivers to use the vehicle.
- there is no visual indicator that the pedal is secured.

- an audible click to indicate proper engagement may be heard but could potentially be muffled by carpeting or the sound of the vehicle running.
- the location of the roller position on the OEM pedal as well as the location and orientation of the left-side pedal should be visually inspected by the driver prior to each use and by the mechanic at each routine service.
- the instructions suggest that the pedal assembly be regularly cleaned and maintained, maintenance inspections be performed at least every six months and that the pedal be inspected before each use.

Use of Pedal

- the Owners & Installation Manual clearly shows the correct location of the left-side pedal such that it does not interfere with brake pedal function.
- the manual also states that only trained drivers are to use the pedal.
- there is a stopper plate that prevents the inadvertent application of the OEM pedal. It also prevents the actuator arm from flipping backward off the OEM accelerator pedal.
- the manual stipulates that the stopper plate is not to be used as a footrest.

2. MPD, Model 3545

Installation

- the assembly is designed as a quick release for removal from the vehicle to allow nondisabled drivers to use the vehicle.
- the manual release of the assembly has a coloured visual indicator to identify whether the pedal is secured. It may be difficult to see this indicator when the LFAP is installed in the vehicle.
- the location of the roller position on the OEM pedal as well as the location and orientation of the left-side pedal should be visually inspected by the driver prior to each use and by the mechanic at each routine service.
- instructions for the cleaning and maintenance of the assembly are quite clear, with steps to be taken every three months and the recommendation that the pedal assembly be serviced every six months by an authorized dealer.
- the instructions also suggest inspection of the device prior to every operation.

Use of Pedal

- the Installation and Owners Manual clearly shows the correct location of the left-side pedal such that it does not interfere with brake pedal function.
- the manual also states that only trained drivers are to use the pedal.

- there is an accelerator guard that prevents the inadvertent application of the OEM pedal. It also prevents the actuator arm from flipping backward off the OEM accelerator pedal.
- the manual stipulates that the accelerator guard is not to be used as a footrest.

3. Howell Ventures, Sure Foot

Installation

- the assembly is designed as non-removable from the vehicle.
- for a nondisabled driver to operate the vehicle, the left-side pedal must be flipped away from the assembly and rest on the floor.
- instructions provided with the product are very sparse and do not suggest any spacing of the pedals.
- the location of the roller position on the OEM pedal as well as the location and orientation of the left-side pedal should be visually inspected by the driver prior to each use and by the mechanic at each routine service.
- the instructions offer no suggestions for service or maintenance of the LFAP.

Use of Pedal

- there is no mention of training in the instructions.
- there is no right-side pedal stop/guard.
- the design requires that the LFAP pedal assembly flip out of the way for use by nondisabled drivers. This feature could result in the pedal falling out of place during operation.

4. MPS, Left Foot Accelerator

Installation

- the assembly is designed as a quick release for removal from the vehicle to allow nondisabled drivers to use the vehicle.
- the manual provides vague spacing suggestions for the left-side pedal and roller position: "be sure to leave enough clearance".
- there is no clear visual indicator that the LFAP is secured.
- there is no information regarding service and/or maintenance of the LFAP.

Use of Pedal

- the manual suggests adjusting the location of the left-side pedal to a position that is comfortable for the user.

- the manual suggests getting training, and even offers suggestions on where to locate proper training.
- there is no OEM pedal stop/guard; however, there is a mechanical stop that restricts the backward motion of the actuator arm beyond the OEM pedal idle position.

5. Drive-Master, Model GS-150

Installation

- the assembly is designed for removal from the vehicle for use by a nondisabled driver.
- the release mechanism may become loose by use of the pedal, allowing the assembly to become dislodged during use.
- there are no suggestions for service or maintenance.
- pictures illustrate the proper positioning of the left-side pedal with respect to the other pedals, as well as the proper roller position.
- installation instructions state that the assembly should only be installed for people who hold a valid prescription for an LFAP.

Use of Pedal

- it is suggested that a user obtain instruction before using the LFAP.
- there is a protector plate over the OEM pedal preventing the OEM pedal being depressed inadvertently and restricting the backward motion of the actuator arm beyond the OEM pedal idle position.

TABLE A2 - APPENDIX A
TASK AND ERROR ANALYSIS FOR INSTALLATION OF LFAP

Task Step	Information Requirements	Potential Errors	Consequences
Ensure all parts are accounted for.	Are all parts present?	Checking not done.	Necessary parts are missing.
Orient the LFAP assembly appropriately on the floor.	What is the proper positioning as determined by the manufacturer?	Incorrectly oriented.	When secured, the assembly will not be in the correct location.
Adjust the roller position on the OEM pedal.	What is the correct location of the pivot point of the OEM pedal?	Roller placed in the incorrect position.	Pedal can jam in place or roller could fall off OEM pedal.
Mark the configuration of holes to be drilled.	What is the orientation of the holes as determined by the manufacturer?	Holes marked in the wrong location.	Holes in the bracket/plate won't line up with holes in vehicle.
Identify any obstructions on the vehicle (i.e., frame, hoses, wires).	Where will the holes to be drilled pass through? What vehicle components are located in the area where the holes will be drilled?	Checking not done. Location of holes incorrectly determined.	Installer has drilled through electrical wires, hoses or other vehicle component causing personal and/or property damage.
Drill holes.	Where is the location of holes to be drilled? What size holes need to be drilled?	Holes drilled in wrong location. Holes drilled too large.	Holes in the bracket/plate won't line up with holes in vehicle; bracket cannot be properly secured.
If necessary, cut the cross-axle assembly.	Does the cross-axle assembly require cutting? If cutting required, how much?	Cut too much. Cut too little, or not at all.	LFAP pedal cannot be properly positioned or mounted in the vehicle.

Position the mounting bracket/plate.	Where are the holes?	Not placed over holes.	Bracket/plate cannot be secured to vehicle.
Insert and secure bolts in place.	Have the correct fasteners been used? Are the fasteners properly tightened?	Bolts/nuts not fully tightened.	Assembly is not secure.
Adjust the left-side pedal spacing from the brake.	How far should the OEM pedal be from the brake?	Pedal placed too close to the brake. Pedal placed too far from the brake.	Pedal cannot be applied without also applying the brake. Driver may have difficulty locating the pedal.
Make other adjustments as stated by the manufacturer.	Have all the instructions been properly implemented?	Assembly incomplete or unsafe.	LFAP may not function properly or may fail in use.

APPENDIX B

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